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SOME EXPERIMENTS ON THE CONDENSATION OF WATER-VAPOUR ON DUST NUCLEI

By

G. R. PARANJPE **H. D. MIRCHANDANI** **Y. G. NAIK**

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1. Introductory

The diffraction rings, seen in a cloud when we look through it at a source of light, serve as the best method of measuring the radius of drops forming the cloud. These diffraction rings are known as corona rings.

The corona method is comparatively easy to manipulate and, based as it is on the diffraction of light, can faithfully give an instantaneous value of the average radius of drops in a cloud, which may not remain in suspension for a long time. This method, therefore, facilitates the study of the various phenomena which depend on the size of the condensed drops.

The diffraction theory of the corona formation has been worked out by Verdet[1]. If monochromatic light is used, the successive diffraction rings occur at regular intervals, depending on the wave-length of light used and the radius of drops.

Experiments to verify this theory have been carried out by a number of investigators, *viz.* Fraunhofer and Doule[2], while the problem of condensation of water has been extensively studied by Aitken[3], Barus[4], C. T. R. Wilson[5] and Mecke[6]. C. T. R. Wilson discusses the condensation in three aspects, namely, occurrence of condensation—

(*a*) in the absence of any nuclei; in such a case the condensation will not occur unless the expansion ratio is greater than 1·4;

(*b*) in the presence of charged nuclei only; in this case the condensation will just begin to occur when the expansion ratio is greater than 1·3;

and (*c*) in the presence of dust nuclei; the expansion ratio of 1·25 or less is sufficient in such cases for causing condensation.

Aitken studied the colour phenomenon with different expansion ratios. Barus and Mecke used corona method and studied the changes of the colour of the corona with different sizes of the drops.

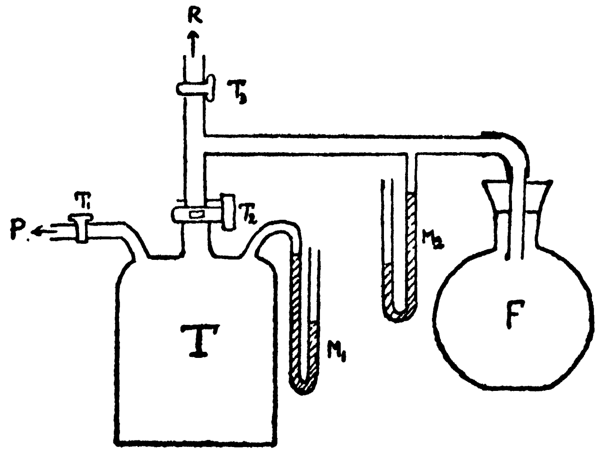
The object of this investigation was to study more closely the various factors that contribute to the formation of drops and their sizes. So far, the work was carried out mainly under definite set of conditions. The condensation was usually divided into two groups *viz.* fog-like condensation and rain-like condensation. No mention appears to have been made in the literature of the subject, regarding the influence of the number of dust nuclei either on the formation of the cloud or on the size of drops taking part in it.

(i) The present work was first planned to study the changes in the size of drops, when different number of nuclei were available for condensation. After a careful investigation, it was found out that the size of the drops depended on the number of nuclei, even though the expansion ratio and the temperature of the chamber remained the same.

(ii) Cunningham[7] and Bromwich[8] had shown that Stokes law does not hold good in its bare form in the case of a settling cloud. Their results have been utilized in interpreting the experimental data obtained in the present series of measurements.

2. *General method of work*

The cloud was produced in a flask having a capacity of more than 10 litres. An airtight metal tank, about 4 to 5 times larger than the flask, was used for creating sudden expansion in the flask. The area of the bore of the tap—connecting the tank and the flask was about 1 sq. cm. The diagram of the apparatus is given below.



F—The experimental flask for producing cloud.

M_2—Manometer for the flask.

T—Big tank for creating expansion in the flask.

P—Tube leading to the pump, with a stop-cock T_1.

T_2—Stop-cock connecting F &T.

R—Tube connecting F to the reservoir containing dust nuclei.

M_1—Manometer for the tank.

The source of light was a 1000 Watt electric lamp and it was kept at a distance of about 5 to 6 meters from the flask. When the light of the lamp was brought to a focus at different points lying between 3 to 5 meters away from the flask, it was observed that the size of the corona ring remained unaltered, indicating that in this case the beam of light could be regarded as parallel for all purposes.

The formula for determining the radius of the drops requires the sine of the angle subtended by the radius of the corona at the eye of the observer. A theodolite was used to read the angle θ directly. The horizontal readings of the subtended angles were more reliable than the vertical on account of the fact that in the latter there were slight distortions in the neck and in the bottom of the flask. In the central part, the ring was quite regular and well-defined. The theodolite was kept at a distance of one meter from the flask. The angles could be read in minutes involving not more than 1% error.

Observed through a red-glass filter, the diffraction rings appeared separated by dark rings. The width of the dark ring increased as the corona rings became larger and it also became dimmer. Measurements were always made at the centre of the dark rings.

The fine definition of the rings suggests that the drops do not differ very much in size from each other in any experiment and that the measurements can be taken to refer to the average size.

As soon as an expansion is made, the drops begin to grow and reach a final steady size in a fraction of a second. This rapid growth of the drops can be seen by a contracting corona which remains stationary at a final smaller size for one particular expansion ratio. This size remains unaltered even when the cloud has almost settled down under gravity. A reverse phenomenon can be observed by bringing the air in the flask to its initial pressure before the cloud completely settles down. The corona ring, in this case, slowly expands, showing that the drops become smaller on account of evaporation.

For obtaining nuclei of nearly the same size and of the same material for comparative measurements, an incense stick of a particular brand was burnt for various lengths of time in a large closed reservoir (cupboard) of about 3000 litres capacity. (Incense stick is prepared by rolling some paste of a combustible material on a long fine wooden stick. It produces a lot of smoke particles, when lighted.) The air under investigation was sucked into the flask through a long tube from the reservoir.

Charged nuclei are known to affect the sizes and also the velocity of fall of the condensed particles, and it was therefore ascertained that the nuclei in these experiments were invariably uncharged.

All experiments were performed at room temperatures and for each set, temperature was always recorded.

After every expansion a time of at least five minutes was allowed to pass before making another expansion.

3. *Some useful formulae*

(1)* Calculation of the size of the drops:

The radius of the drops is obtained from the following equation :—

$$\sin\theta = (n+0{\cdot}22)\,\frac{\lambda}{2a}$$

where θ = angle subtended by the radius of the corona ring at the eye of the observer
n = order of the ring
λ = mean wave-length of light forming the corona
a = average radius of drops.

For $n=1$ and $\lambda=7594$ A.U., the mean transmission wave-length of the red glass filter, the formula reduces to

$$a = \frac{1{\cdot}22 \times 7594 \times 10^{-8}}{2\sin\theta}\ \text{cms.}$$

(2) Calculation of the expansion ratio:

Expansion ratio $= V_2/V_1$

$$= \frac{P-\sigma}{P-p-\sigma}$$

where V_1 = volume before expansion
V_2 = volume after expansion
P = initial pressure in the flask
p = manometer reading after expansion
σ = pressure of saturated water vapour.

P, p, and σ are known for each experiment.

(3)† Calculation of the quantity of water condensed in an adiabatic expansion according to the method explained by C. T. R. Wilson.

q, the quantity of water condensed per c.c.

$$= d_1 - d \quad \ldots\ldots\ldots\ldots \quad \text{(i)}$$

where d_1 = density of saturated water-vapour before condensation.
d = density of water-vapour left over after the condensation is complete.

d is obtained from the following equations:

$$d = d_1 - \frac{C_v\,M}{L}(t_1 - t_2) \quad \ldots\ldots\ldots\ldots \quad \text{(ii)}$$

---

* Humphrey's *Physics of the Air*, p. 528.

† C. T. R. Wilson Phil. Trans. Roy. Soc. 189, p. 265, 1897

where C_v = specific heat of air at constant volume
M = density of moist air at the reduced pressure
L = latent heat of vaporisation
t_2 = adiabatic lowering of temperature
t_1 = intermediate temperature at which the condensation is complete.

Using (i) and (ii) q can be calculated.

(4) The number of drops formed :

N, the number of drops per c. c. can be calculated from the following equations :

$$\frac{4}{3}\pi a^3 \rho N = q$$

where ρ = density of water
a = radius of the drops
q = quantity of water condensed per c.c.

4. *On the influence of the number of nuclei on the size of the drops*

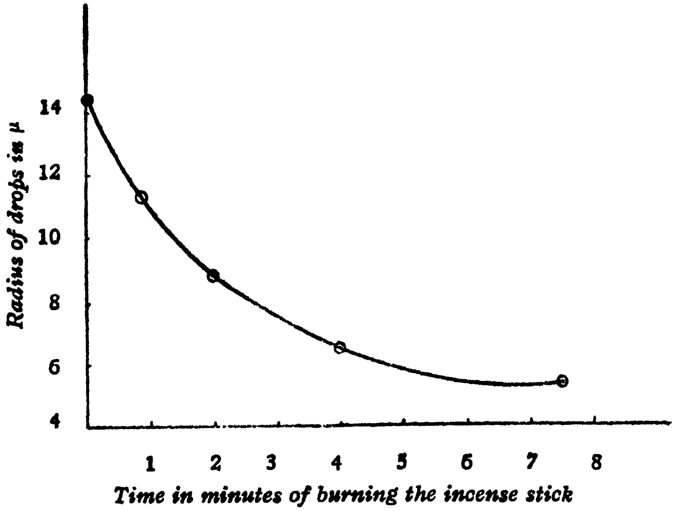
In the literature on the subject of condensation no mention appears to have been made of the fact that under identical conditions of temperature and expansion ratio, the resulting water drops may not necessarily be of the same size, if the number of nuclei does not remain the same. On the contrary different authorities have given results showing only the effect of the expansion ratio on the size of the condensed drops either at one or at different temperatures.

The influence of the number of nuclei was suspected for some time but it is now realized that the number of nuclei present in the vapour before condensation appears to have a considerable influence on the size of the resulting drops. The radius of the drops varied from 7·8 μ to 6·5 μ, under identical conditions of temperature and expansion ratio, where only the number of nuclei was doubled. This appears to have escaped attention so far.

In order to ascertain whether or not the size of the drops depended mainly (if not wholly) on the available number of dust nuclei, the following procedure was adopted. Dust particles were produced by burning an incense stick for various lengths of time in the large reservoir and the corresponding change in the size of the drops was observed, keeping all other conditions, the same. Fresh number of nuclei were drawn into the dust-free flask from the reservoir containing nuclei at a constant pressure-difference. The size of the drops was then observed by producing a cloud at a fixed expansion. It will be seen from the figures given below that the size of the drops decreases as the number of available nuclei increases, TABLE No. I

Expansion Ratio.	Quantity of water condensed per c. c. x 10^{-6} gms.	Radius of drops in μ.	*Time in minutes of burning the incense stick.
1·177	4·01	14·34	0·
		11·47	0·75
		8·89	2·0
		6·66	4·0
		5·31	7 ·0

The change in the size of the drops is initially very rapid, but with increasing number of nuclei, it becomes slow and appears to reach a limiting value. This will be evident from Graph No. I which shows the relationship of the radius of the drops with the time of burning the incense stick, which is proportional to the number of nuclei.



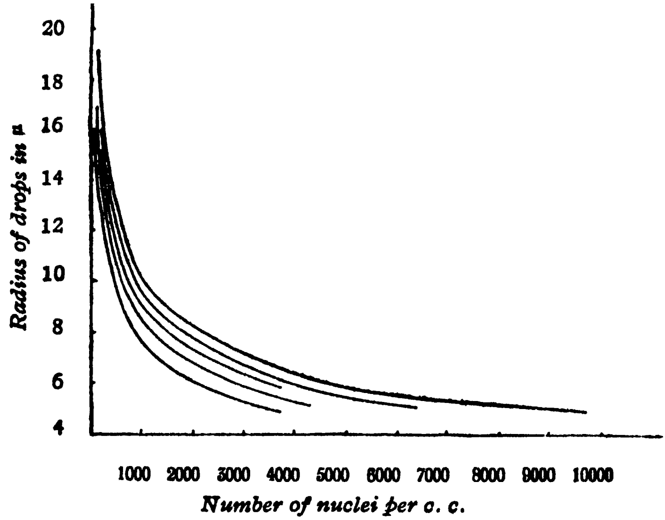
Graph No. I.

Series of experiments were next performed with the flask containing varying number of nuclei and the results obtained from them are shown in the curves. They indicate that different-sized drops can be formed for the same expansion ratio. This becomes

---

* Proportional to the number of nuclei.

possible only because the number of nuclei in each experiment is different, while the quantity of water remains unaltered. All observations were taken at a temperature of 28⁰ C., while some taken at 20⁰ C. showed the same phenomena, but they are not given here. The results of these experiments are plotted in the Graph No. II. Each curve is for one fixed expansion ratio. The different ratios employed are 1·074, 1·106, 1·140, 1·176 and 1·215. Curve next to the origin corresponds to the first expansion ratio. Different numbers of particles were inserted and the sizes of the drops were measured.



Graph No. II

These graphs show the relationship between the radius of drops and the number of nuclei present (*i. e.* drops formed). All the graphs show a tendency to become asymptotic to the size axis and also to the axis representing the number of nuclei. The first indicates that drops can be formed in enclosures which contain very few nuclei. The second indicates that drops appear to reach a limiting value determined by the size of its nucleus. Similar changes were observed at a temperature of 20⁰C.

To account for the large variation of the size of the drops from 18 μ to 5 μ, it is necessary to assume (1) that all the nuclei are used up in the formation of drops and (2) that each drop contains one and only one nucleus. The clear definition of the rings supports the second assumption while the first one can be justified by the results quoted on the next page.

Curves give the number of drops formed for a particular size and expansion ratio and according to the assumptions made, this is also equal to the number of nuclei present normally, that is when they are not too many.

5. On the change in the size of drops at different expansion ratios

In the light of the discussion given on the foregoing page it can be seen that wide variations in the size of the drops can be caused by different number of available nuclei. A quantitative study of the changes in the size of the drops at different expansion ratios, makes it absolutely necessary, therefore, that the number of nuclei in the flask must be maintained constant.

TABLE III

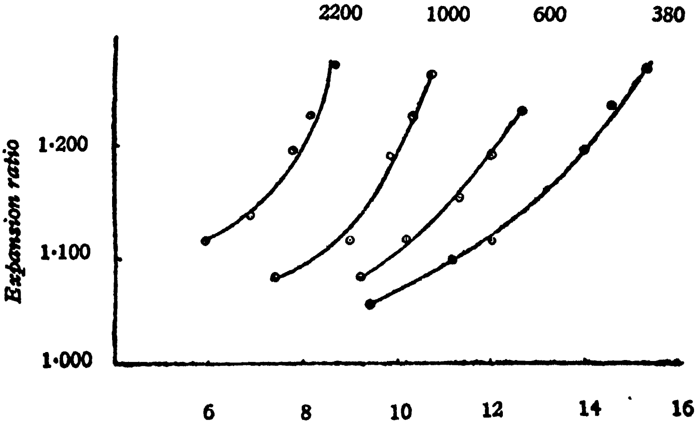
Expansion Ratio	Quantity of water condensed per c.c. x 10^{-6} gms.	Radius of drops in μ	No. of drops per c.c. (calculated)
(*a*) 1·105	2·47	5·94	3100[1]
1·126	2·84	6·84	2400
1·182	3·80	7·85	2100
1·213	4·08	8·25	2100
1·255	4·77	8·70	2100
(*b*) 1·073	1·80	7·44	1100
1·102	2·40	9·04	900
1·175	3·71	9·83	1100
1·210	4·10	10·41	1150
1·247	4·67	10·82	1100
(*c*) 1·074	1·82	9·25	590
1·106	2·52	10·21	620
1·140	3·17	11·21	610
1·176	3·69	12·00	610
1·215	4·36	12·70	620

[1] This is the only number which appears to be very high for this particular set.

Expansion Ratio.	Quantity of water condensed per c. c. x 10^{-6} gms.	Radius of drops in μ.	No. of drops per c. c. (calculated)
(*d*) 1·052	1·29	9·43	390
1·088	2·12	11·21	390
1·105	2·47	11·97	370
1·182	3·80	14·08	380
1·222	4·36	14·61	400
1·251	4·70	15·44	380

It is interesting to note that in the last column of the above tables the number of drops is nearly the same for each set. The C. T. R. Wilson method of calculations, which is a purely theoretical one, lends support to the first assumption made on page 11.

The results as plotted in Graph No. III indicate that the growth of the drops is rapid in the beginning but becomes very slow for higher expansion ratios.



Average number of nuclei is given against each curve

Graph No. III

With different expansion ratios the quantities of water condensed are also different and this is the reason why the size of the drops alters, even though the number of nuclei is nearly the same.

6. *On the application of Stoke's law*

Now that the size of the drops is a well determined quantity by the use of the corona method, it is possible to verify some of the conclusions arising out of Stoke's Law.

For falling drops,

$$mg = X = 6\,\pi\,\eta\,a\,V,$$

where X is the force acting downwards and is equal to $m\,.\,g$ where m is the mass of the drop of radius a, falling with a velocity V through a medium of viscocity η. g is the acceleration due to gravity.

$$\text{therefore } \frac{X}{6\pi\,\eta a}\cdot\frac{1}{V} = 1 = \frac{V'}{V}$$

where V′ = calculated velocity knowing a independently

and V = observed velocity.

If Stoke's law were correct, in its bare form in case of a cloud, V′ and V must be equal.

Cunningham[7] arrived at a formula, for the rate of fall of a cloud of small particles,

$$\frac{X}{6\pi\,\eta a V} = \left\{ 1 + \left(\frac{9}{4}\cdot\frac{a}{b}\right) + \left(\frac{81}{16}\cdot\frac{a^2}{b^2}\right)\ldots\ldots \right\} \quad .. \text{(i)}$$

$$\left(\text{which is equal to } \frac{V'}{V}\right)$$

assuming that each drop of radius a has a spherical shell of air of radius b moving with it. If the size of the shell were to vary with the size of the drop, different values of velocity V′ could be obtained. Cunningham gives the following table indicating corrections for different values of b/a.

TABLE IV

b/a =	1·63	3·26	4·08	. . . .	24·5	∞
$\frac{X}{6\pi\eta a V}$ =	7·29	2·10	1·76	. . . .	1·08	$1 = \frac{V'}{V}$

Using the present apparatus for the production and measurements of the size of the cloud particles, a number of observations were made, wherein V the velocities of fall of the cloud were directly measured by watching the well-defined top of the settling cloud and the velocities V′ were calculated on the assumption of the validity of Stoke's law.

The ratio V'/V was found to have a mean value of 2·04 averaged over a set of 21 experiments, wherein the sizes of the drops varied between 4·77 μ and 8·94 μ. The lowest and the highest value of the ratio was 1·90 and 2·13 representing a maximum deviation of about 5%. The temperature was 26·5° C.

From the value of $\frac{X}{6\pi\eta a V} = 2{\cdot}04$, the ratio of b/a works out to be 3·599 from equation (i).

In a recent paper Bromwich[8] arrived at the following formula from a general treatment of the problem, taking into consideration the slip of the drop against air.

$$\frac{X}{4\pi\eta a^2} = \left(\frac{3}{2} + \frac{3}{2}qa + \frac{1}{6}q^2a^2\right)\frac{V}{a}$$

(where q = constant)

which can be written as

$$\frac{X}{6\pi\eta a V} = \left(1 + qa + \frac{1}{9}q^2a^2\right) \ldots\ldots\ldots (\text{ii})$$

This equation has the same form as the Cunningham's.

Taking $\frac{X}{6\pi\eta a V} = 2{\cdot}04$, the experimentally determined value qa comes out to be 1·064 from (ii).

The terms $\frac{a}{b}$ of Cunningham and qa of Bromwich appear to be constant at least within the range of observation and at the temperature of the experiments. This indicates that the radius of the shell of air moving with the drop, becomes bigger as the drop increases in size and vice versa, in case of Cunningham's formula. The quantity q which according to Bromwich should be a constant appears to be an inverse function of a, so that qa is a constant.

The resulting equation for Stoke's Law at 26·5° C. for a cloud of water drops will be,

$$\frac{X}{6\pi\eta a V} = 2{\cdot}04 \text{ but } X = mg = \frac{4}{3}\pi(\rho - \sigma)a^3 g$$

where ρ = density of water

and σ = density of air

which simplifies to

$$V = \frac{1}{9{\cdot}18}\frac{(\rho - \sigma)a^2 g}{\eta}$$

$$\therefore V = a\left(\frac{9{\cdot}18 \times \eta \times V}{(\rho - \sigma).g}\right)^{\frac{1}{2}}$$

7. *Summary*

The present work was taken up in the first place to investigate the effect of the number of nuclei on the size of the drops forming a cloud. It was found that the size of the drops can be controlled at will and hence other problems based on the size of the drops were investigated.

1. Size of the drops in an expansion is largely influenced by the number of nuclei present. As the nuclei go on increasing the size of the drops goes on diminishing for a particular expansion ratio and temperature.
2. The growth of the drop with increasing expansion ratio, where the number of nuclei was nearly the same is continuous. At higher expansion ratios, the growth becomes considerably slow and is likely to be mistaken as abrupt.
3. An experimental estimate of the correction for Stoke's law is obtained and results arising out of it have been discussed.

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STABILITY OF LIQUID SODIUM-AMALGAMS

By

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1. *Introductory*

A paper recently published by one of us gives an interesting observation made by Mr. R. V. Barave [*Indian Journal of Physics* 1932, VII (1), 95] that the viscosity of a liquid sodium-amalgam goes on diminishing with time and that the initial value is more or less regained if the amalgam is made to suffer a mechanical agitation. The remarks regarding the non-separation of *Na* or any other phase rich in *Na* are based only on an indirect evidence. It was necessary, therefore, to study the sedimentation equilibria for amalgams of different concentrations and see if a direct evidence can be obtained to corroborate them.

Some experiments in this direction were made by Bhatnagar and co-workers [*J. Ind. Chem. Soc.* 1924, I, 81] in connection with their work on the surface tensions of liquid *Na*- and *K*-amalgams, but the concentration they investigated (0·553% *Na*) was far above the range (0·000%–0·312% *Na*) they actually studied. This was another reason why it was decided to undertake this investigation and obtain direct evidence, because the stability of amalgams without actually testing it has always been assumed by the several workers who studied their different physical properties.

There is still another reason of a very fundamental importance which makes this work necessary. The present authors have shown [*J. Phys. Chem.* 2474, *34*, 1932,] that, unlike other theories, the colloid hypothesis explains satisfactorily all the available facts about liquid sodium-amalgams and that the amalgams can be looked upon as hydrargyrophillic colloidal solutions of sodium in mercury with *Na* as the disperse phase, *Hg* the dispersion medium and $(Na_x)Hg_y$ as the colloid micellæ with varying values for x and y. If the amalgams are colloidal solutions, their stability becomes the first object of study.

From the very nature of the work, it was necessary that a more rigorous method had to be followed and the range of observations extended so as to include the first discontinuity concentration.

2. *Experimental : Preparation of the amalgams*

The amalgams were prepared after the manner of T. W. Richards [*J. Amer. Chem. Soc.*, 1922, *44*, 601] by electrolysing a saturated solution of sodium carbonate over pure redistilled mercury which was made the cathode, a platinum foil electrode serving as the anode. After about the desired concentration was attained, the progress of electrolysis was stopped and the supernatant carbonate solution removed. The amalgam was then washed three times with definite quantities of distilled water in order to remove the last traces of the carbonate and washed again three times with pure dry alcohol to remove the last traces of water that might have remained over. The amalgam was next transferred to the capillary filter from which it was sucked into the storing vessel which was filled already with pure dry nitrogen.

In the preparation of the several amalgams the same apparatus, the same quantities of mercury, distilled water and alcohol were used throughout and it may be said that all the amalgams were prepared under the same standard conditions, only the time of electrolysis being different for different concentrations.

3. *The apparatus*

The apparatus used consists essentially of a vertical tube of about 10 m. m. diameter, with many horizontal spouts, in this case seven,

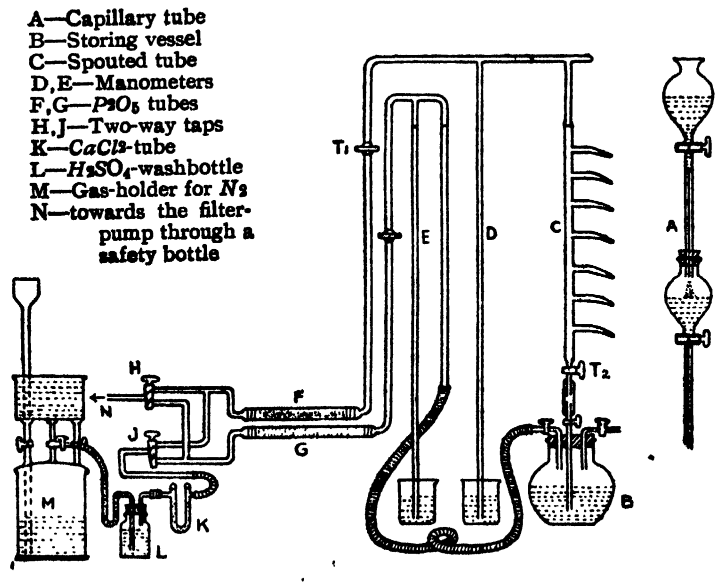

Fig. I

at approximately equal distances (5 cms.) with a tap at the lower end. Each of these spouts was slightly bent downwards and drawn into a fine capillary and sealed. This tube could be connected either to the filter pump or to the nitrogen cylinder alternatively.

By means of two two-way taps and two T joints an arrangement was made by which the same filter-pump and the same gas-holder could be used to fill with nitrogen the tube as well as the storing vessel, each circuit still remaining independent of the other. The whole apparatus as used in these experiments is shown diagrammatically in Fig. 1. By suitably managing the taps H and J, the tube C could be evacuated while the storing vessel B was being filled with dry nitrogen or *vice versa.*

Another important feature of the apparatus is that between the taps T_1 and T_2 there was no rubber joint so that there was no chance of contamination except through glass when the amalgam remained in the tube C for many days and the taps T_1 and T_2 were closed.

Each time the storing vessel B or the spouted tube C was required to be filled with nitrogen, it was first evacuated as much as possible by means of the filter pump and nitrogen was then let into it. Again it was evacuated and re-filled with dry nitrogen. This process of washing the apparatus with dry nitrogen was repeated at least three times to ensure the absence of oxygen and moisture.

4. *Further precautions.*

All the chemicals used in these experiments were Merck's extra-pure.

Nitrogen was prepared chemically by heating a mixture of $K_2Cr_2O_7$, $NaNO_2$ and $(NH_4)_2SO_4$ with a large quantity of water and passed through a mixture of 5 volumes of a saturated solution of $K_2Cr_2O_7$ and 1 volume of concentrated H_2SO_4, in order to remove all the nitrous gases that may be found in small quantities together with Nitrogen (cf. *Dictionary of Chemistry* by Thorpe), before it was stored in the gas-holder.

The grease used for all the taps was prepared according to Baker's formula [*J. Chem. Soc.* 1929, 1661,] which was slightly modified to suit the climatic conditions here, by increasing the proportion of solid paraffin. Since the grease consisted only of solid paraffin which has no action on the amalgams, and of white petroleum jelly which was previously treated with moderately strong caustic soda, it could not affect an amalgam if it came into contact with it while passing through the several taps in the apparatus.

All the rubber-glass joints were covered with a thick coating of a mixture of bees wax and resin (bees wax 40% and resin 60%). This ensured absence of leaks which was tested every time by evacuating the apparatus to the highest possible degree with the filter-pump and keeping it in that condition overnight when next morning no appreciable difference was observed in the manometer.

Special attention was paid to secure a thorough drying of the nitrogen before it was filled into any of the two systems. It was first bubbled slowly through the sulphuric acid wash-bottle L, then passed through the calcium chloride tube K and then turned on to either of the systems through the long P_2O_5 tubes F or G.

That these precautions were enough is shown quite clearly by the nature of the results obtained. If the conditions of the experiments were not satisfactory and the oxygen and moisture were not sufficiently excluded, there ought to have appeared a white incrustation of caustic soda or a saturated solution of caustic soda at the top of the amalgam in the tube C. But no such thing ever appeared and the concentration remained uniform all over the tube.

5. *The procedure of the experiments*

With all the above precautions, an amalgam was sucked into the spouted tube C by evacuating it and keeping the storage vessel open to nitrogen. Every time the tube was filled, it was filled to the same extent *i. e.* to about 5 cms. above the topmost spout. Care was taken to see that the amalgam in the storage vessel was thoroughly agitated just before it was sucked into the spouted tube, so that it may be assumed that the amalgam was homogeneous when it was filled into the tube C. As soon as the filling was complete, nitrogen was let into the circuit and the amalgam was then allowed to remain there undisturbed for over a week under the inert atmosphere of pure dry nitrogen.

After a week, the amalgam was tapped out through the several spouts by breaking the tip of each spout beginning with the topmost. The portion coming out from each spout was collected in a separate test-tube which was closed immediately. Every test-tube was then well shaken and the amalgam in each was pipetted out in three weighing bottles which were weighed previously. Each weighing bottle contained about 1 c. c. of the amalgam. Thus the whole column of the amalgam was divided into eight approximately equal parts, and each part, after a thorough shaking, was further divided into three which were analysed separately. The mean of the three separate analyses was then calculated for each spout and put down as the concentration of the amalgam at that spout.

6. *The analysis*

Each of the twenty-four weighing bottles was then weighed with the amalgam in it and the difference between the previous weight *i.e.* when it was empty, and this weight gave the weight of the amalgam it contained. The amalgam from each bottle was then washed into a separate conical flask containing an excess of 0·01*N HCl*, and there allowed to react with it. After the reaction was complete, the excess of acid was titrated against standard caustic soda (0·01*N* approx.) with phenol-phthalein as the indicator. This gave the quantity of the acid used by the amalgam in each bottle. Thus, knowing the weight of the amalgam in each bottle and the acid required to neutralise it the percentage weight of sodium could be calculated. The results of all these experiments with amalgams of different concentrations are given in Tables I and II. Table I gives the entire data for one concentration and Table II is the summary of eight such different tables obtained for amalgams of eight different concentrations.

TABLE I

Average concentration of Na

0·0274 gm. *Na* in 100 gms. of amalgam

Spout No.	Weight of Amalgam gms.	Acid required 0·01*N HCl* c. c.	Quantity of *Na* per 100 gms. of amalgam gms.	Mean value for each spout gms.	Deviation from the average.
1	14·111	16·77	0·0274	0·0272	—0·0002
	13·637	16·34	0·0269		
	14·291	16·97	0·0273		
2	14·442	17·02	0·0271	0·0275	0·0001
	15·033	18·33	0·0280		
	14·836	17·72	0·0275		
3	14·921	17·78	0·0274	0·0274	0·0000
	15·671	18·69	0·0274		
	13·978	16·61	0·0273		
4	12·431	14·76	0·0273	0·0273	—0·0001
	14·700	17·58	0·0275		
	14·743	17·42	0·0272		
5	14·550	17·47	0·0271	0·0274	0·0000
	15·039	18·13	0·0277		
	14·576	17·50	0·2749		
6	15·295	18·43	0·0277	0·0274	0·0000
	13·976	16·62	0·0273		
	16·341	18·43	0·0272		
7	15·675	18·69	0·0274	0·0272	—0·0002
	14·945	17·47	0·0271		
	14·612	17·42	0·0274		
8	14·518	17·43	0·0279	0·0274	0·0000
	14·347	16·97	0·0270		
	14·034	16·67	0·0273		

Maximum error — 0·7%

If the amalgams are lyophobic $(\rho-\rho_m)$ must be fairly large because of the difference between the densities of *Na* and *Hg*. If however, they are lyophillic $(\rho-\rho_m)$ can be very small depending on the degree of hydrargyration of the *Na* particles.

If the coagulation is proceeding at the rapid rate suggested by Barave's data within eight days' time r must become fairly large. This means that the sedimentation velocity can be what it is only when $(\rho-\rho_m)$ is extremely small, that is when the amalgams are colloidal solutions of the lyophillic type.

Thus, it will be seen that the observed lack of sedimentation does not go against the colloid hypothesis.

In conclusion, the authors take this opportunity to thank Dr. T. S. Wheeler and Dr. Mata Prasad for the interest they took in this work during the stages of interpretation.

Summary

Sedimentation equilibria are studied for liquid sodium-amalgams of various concentrations between 0·0000% and 0·1406 % of *Na* by weight by following a sufficiently rigorous method, and the observed lack of sedimentation is shown to be helpful in deciding whether the amalgams are lyophobic or lyophillic colloidal solutions of *Na* in *Hg*.

A NOTE ON THE EXISTENCE OF CRITICAL POTENTIAL CHARACTERISTIC OF COAGULATION OF A COLLOID BY AN ELECTROLYTE

By

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The widespread opinion, first put forward by Hardy (*Proc. Roy. Soc.* Vol. 66,110,1900), that coagulation begins only when colloid particles are completely discharged and the iso-electric point is reached, has been found to be erroneous by Powis (*Zeitschr. f. physik. Chemie*, Vol. 89,186,1915). He determined, by means of cataphoretic experiments, the charge upon oil drops at various concentrations of the coagulator and found that coagulation begins as soon as the electrokinetic potential or the electric charge falls below a certain absolute value. This value of the electro-kinetic potential, at which coagulation first begins, has been termed by Freundlich the "first critical potential" and is said to have the same characteristic value for any particular sol when coagulated with salts having coagulating ions of different valencies. Burton's cataphoretic experiments (*Phil. Mag.*, Vol. 17, 583, 1909) with positively charged copper oxide sol showed a similar behaviour. The results of Kruyt, Roodvoets and van der Willigen (*Fourth Colloid Symposium*, 1926, pp. 304-310) and of Kruyt and van der Willigen (*Z. physikal Chem.*, Vol. 130,170, 1927) have shown that their results also support Powis' theory of critical potential.

Freundlich has utilised the existence of the first critical potential to explain the phenomenon of "slow coagulation". According to him slow coagulation begins after the first critical potential value is reached. The slow coagulation passes into rapid coagulation when the value of the potential difference becomes zero or the iso-electric point is reached (Freundlich's second critical potential). In the region of slow coagulation all collisions between the particles do not bring about coalescence. Only those collisions are successful in which the velocity of the particles exceeds a certain value. With the lowering of the value of the potential difference below the critical value, the repulsive forces between the particles become less and less and ultimately disappear at the iso-electric point. Therefore at the iso-electric point all collisions will be successful in spite of the fact that the velocity with which the particles move might be very small in some cases. Between the value of the critical potential and the iso-electric point when the charge has not been completely neutralised, the velocity of the particles must reach a certain value in order to overcome the repulsive forces between them. Desai (*Trans. Faraday Soc.*, Vol. 24,181,1928) has discussed the reasons of the non-observance of the slow coagulation region by many investigators and shown that besides the suitability of the methods employed to measure the rate of coagulation, the purity and the concentration of the colloid, the concentration of the electrolyte and the valency of the coagulating ion are important factors to be reckoned with which govern the appearance of the 'S' shaped curves of the coagulation velocity and the auto-catalytic nature of the coagulation process (Patel and Desai, *Trans. Faraday Soc.*,Vol. 26,128,1930).

The existence of the critical potential has been recently called into question by Mukherjee and co-workers. On the basis of some of their investigations Mukherjee, Roy Chaudhari and Rao (*Journ. Indian Chem. Soc.*, Vol. 5, 697, 1928; also cf. Mukherjee and Chaudhari, ibid. Vol. 2, 296, 1925 and Mukherjee, Chaudhari and Rai Chaudhari, ibid. Vol. 4, 493, 1927) have concluded that there is no definite critical potential characteristic of the coagulation of a colloid by an electrolyte as has been suggested by Powis (loc. cit.). Experiments of Powis (*Journ. Chem. Soc.*, Vol. 109, 734, 1916) upon As_2S_3 sols showed that although the value of the critical potential with $BaCl_2$,$AlCl_3$ and $Th(No_3)_4$ was almost the same, the same was not found to be the case with salts having univalent cations—HCl and KCl. Powis ascribed this behaviour in the case of univalent cations to the higher concentration of the sol employed and to the salting out effect of the potassium salt at a higher potential. According to Freundlich (*Colloid and Capillary Chemistry*, Eng. Translation, 1926, p. 419) the abnormality observed by Powis might be connected with hydration and that markedly electrocratic sols will show a uniform behaviour not only with multivalent coagulating ions but also with univalent coagulating ions.

It is considered that it is not only the electrocratic nature of the sol which will decide strict adherence to the idea of critical potential but also the nature of the stabilising ion and the valency of the coagulating ion of the electrolyte employed in bringing about coagulation. It is generally observed that with electrolytes having a univalent coagulating ion the cataphoretic speed first increases and reaches a maximum value on the addition of small amounts of an electrolyte, and then decreases on the addition of further larger amounts of the electrolyte. The initial increase in the cataphoretic speed on the addition of an electrolyte is due to the "preferential" adsorption of the similarly charged ion (the word "preferential" is used to show that the ion goes to the inner side—nearest to the particle—of the double layer). The value of the maxima in the cataphoretic speed—concentration curve with different electrolytes with the same univalent coagulating ion but different similarly charged ions will not be the same due to a difference in the adsorbability of those ions. With electrolytes containing polyvalent coagulating ions the initial increase in the cataphoretic speed will not be noticed at all because of their very marked coagulating power, the preferential adsorption of the similarly charged ions being not allowed to take place. The value of the maxima being different with different similarly charged ions and being obtained at different equivalent concentrations of the electrolytes, it is possible that the sol may not begin to coagulate at the same value of the potential. For this will be equivalent to starting with sols having different initial charges and with intermicellary liquids of different compositions. The changes in the intermicellary liquid will considerably modify the behaviour of the sols with regard to the value of the critical potential at which they may begin to coagulate and will not allow them to coagulate with the same equivalent amounts of different electrolytes.

Some results of cataphoretic speed measurements which are being carried on in our laboratory have shown that the adsorption of the similarly charged ions being negligible in the case of a fairly pure sample of the colloid (dialysed for a long period and hence containing only traces of the peptising agent), the value of the critical potential at which the coagulation begins may be the same even in the case of electrolytes with univalent coagulating ions but with different similarly charged ions.

INFLUENCE OF ACIDITY OF GELATINE SOLUTION ON ITS INHIBITIVE POWER AND ON THE SOLUBILITY OF SILVER CHROMATE

By

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It has been shown by various workers (Williams and Mackenzie, *J. Chem. Soc.*, Vol. 117, 844, 1920; Bolam and Mackenzie, *Trans. Faraday Soc.*, Vol. 22, 151, 162, 1926; Hedges and Henley, *J. Chem. Soc.*, 2714, 1928) that unhydrolysed gelatine has to a very marked degree the power of retarding the appearance of red colour in a mixture of aqueous solutions of silver nitrate and potassium chromate. Electromotive force and conductivity data (Bolam and Mackenzie, loc. cit.; also see Desai and Nabar, *Trans. Faraday Soc.*, Vol. 28, 449, 1932) indicate that prior to the change from yellow to red the silver chromate is in solution and not in the colloidal state (Chatterjee and Dhar, *Trans. Faraday Soc.*, Vol. 23, 23, 1927; *J. Indian Chem. Soc.*, Vol. 5, 175, 1928). Desai and Nabar (*J. Indian Chem. Soc.*, Vol. 9, 141, 1932) have studied the effect of addition of acetic acid to gelatine solution on the Liesegang rings of silver chromate and found that an increase in the acidity of gelatine is accompanied by a decrease (i) in the time after which the first ring appears, (ii) in the distances between the same successive rings and (iii) in the number of rings which can be obtained. In what follows the results obtained on the influence of acidity of gelatine solution (addition of acetic acid) on its inhibitive power and on the solubility of silver chromate have been presented.

The amount of silver ion in the chromate mixtures was determined electrometrically as before (Desai and Nabar, *Trans. Faraday Soc.*, Vol. 28, 449, 1932). In Table I (on p. 29) are given the results obtained with a saturated solution of silver chromate under different conditions.

From this Table we find that the concentration of *Ag* ion in a saturated solution of silver chromate is not increased by a slight increase in the acidity of water or of gelatine (by the addition of acetic acid) as shown by the constancy of the e. m. f.

e. m. f. measurements of the mixture N/100 silver chromate + N/100 potassium chromate + gelatine (to which varying amounts of

TABLE I

Saturated solution of silver chromate (Temp. 30°C) in	Observed e. m. f. volts.
Conductivity water	0·8575
3 per cent gelatine solution. $p_H = 5·15$	0·8582
Water $p_H = 5·15$ (addition of acetic acid)	0·8569
3 per cent gelatine pH = 5·00 (Addition of acetic acid)	0·8566

acetic acid were added) were carried out and the results of these experiments are given in Table II.

TABLE II

Gelatine having p_H.	Initial e. m. f. of the system volts	Calculated e. m. f. volts	Remarks
5·15	0·9185	0·9234	Precipitate appears after 98 minutes.
5·10	0·9187		Precipitate does not appear even after 8 days; the mixture remains clear yellow.
5·00	0·9181		Do

The results indicate that addition of acetic acid to gelatine markedly increases its inhibitive power.

If we consider together the results given in Tables I and II, we find that although slight changes in p_H of gelatine do not affect the silver ion concentration in a saturated solution of silver chromate in gelatine, they markedly affect its inhibitive power and that the smaller the p_H of gelatine, the greater is its inhibitive power.

In Table III are given the amounts of silver chromate which can remain in ionic condition (clear yellow mixture of 3 per cent unhydrolysed gelatine and equivalent amounts of silver nitrate and potassium chromate before the appearance of the red precipitate) for 98 minutes in gelatine having different p_H.

TABLE III

pH of gelatine	Amount of silver chromate which can remain in ionic condition for 98 minutes
5·15 (gelatine as such)	$2{\cdot}87 \times 10^{-3}$N
5·10 (gelatine and acetic acid)	$4{\cdot}10 \times 10^{-3}$N
5·00 (gelatine and more acetic acid)	$5{\cdot}92 \times 10^{-3}$N

It will be seen from the results that the amount of silver chromate which can be kept in ionic condition or the degree of supersaturation increases with a decrease in the *pH* of gelatine or with an increase in its inhibitive power (Table II).

The results given in Tables I and III would appear to be inconsistent. It is, however, not so, for the effect due to the initial presence of the acid before the solutions are mixed and the precipitate of silver chromate comes out will not be the same as the effect produced when acid is added after the precipitate has already appeared.

These results show that (i) the concentration of silver ion in a saturated solution of silver chromate does not increase due to slight changes in the acidity of water or of gelatine (addition of acetic acid), (ii) the inhibitive power of gelatine increases with a decrease of its *pH* and (iii) a sample of gelatine with lower *pH* can keep a greater amount of silver chromate in ionic condition than another sample with higher *pH*.

STUDIES IN THE ACYL DERIVATIVES OF ARYL AMINES

By

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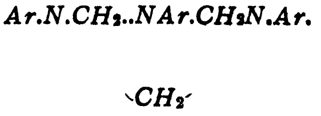
Action of Formaldehyde, Sodium, and Potassium on (1) Acetanilide, (2) Acet-o-toluidide, (3) Acet-p-toluidide, (4) Acet-a-napthylamide, (5) Acet-b-napthylamide.

ACTION OF FORMALDEHYDE

The aromatic amines are very active towards formaldehyde and other aldehydes; so that in some cases the condensation product is precipitated instantaneously at ordinary temperature. (Tollen's B. 17. 657; B. 18. 3302, 3307, Sender, B. 25, 2033. Lettenmayer, B. 25. 2039 etc.), The constitution of the condensation product is usually represented as:—



$$Ar.N.CH_2..NAr.CH_2N.Ar. \quad \backslash CH_2 /$$

$Ar=C_6H_5$, $C_6H_4CH_3$ etc., (*Beilstein* 1929 Ed. Vol. XII pp. 78 777, and 887.) The above constitution is also supported by the formation of condensation products of the type:—

$$Ar.\ NH.\ CH_2.\ NH.\ Ar$$

(Eberhardt and Welter B. 27, 1805, 1807, and 1808)

In this case however of the two hydrogen atoms of the NH_2 group only one is utilised for the condensation and the other is free.

Hence it was found interesting to study the action of aldehydes on aromatic amines in which, one of the H atoms from the NH_2 group is replaced by some other groups. Formaldehyde on the one hand and acetyl derivatives such as acetanalide, acet-o-toluidide etc., were selected for the purpose, they being the most easily available.

When the aqueous solutions of these amides were boiled with 40% formaldehyde solutions alone, or with formaldehyde, alkali, and alcohol (Eberhardt and Welter B. 27, 1805 etc.), products were obtained which seemed to have absorbed formaldehyde.

Melting points were lowered but on thorough drying or on standing for a long time, the melting points rose to the melting points of the original compounds and weights also decreased, thus showing that the absorbed formaldehyde had gone.

This inactivity of the Acyl derivatives towards formaldehyde in contrast to the activity of the original amines suggests that probably the-NH-CO group in the Acyl derivatives has changed into the other form—$N: C.OH$ or that the condensation does not take place because of steric hindrance.

To settle this point, the reactivity of the above compounds towards metallic potassium and sodium was studied.

ACTION OF METALLIC POTASSIUM AND SODIUM

In the literature no potassium or sodium derivatives of the acyl derivatives of the aryl amines can be found except the sodium derivative of acetanalide to which the formula $C_6\,H_5N.\,Na.\,Co.\,CH_3$ is assigned. (Hepp, B. 10, 328.)

Our results can be put down in brief as under :—

1. It was found that the amides were as a rule more active towards potassium than towards sodium.

2. The reaction did not take place vigorously (and in some cases, there was no reaction at all) at ordinary temperature.

3. Continuous boiling in toluene solution for about fourteen hours was necessary till the reaction came to an end. In benzene solution the reaction went on very slowly whereas at the high boiling point of xyiene decomposition set in.

4. Hydrogen evolved briskly in the beginning and slowly as the reaction came to an end.

5. The order of the smoothness of the reaction was as under :— Acetanalide, 2. Acet–o–toluidide, 3. Acet–p–toluidide, 4. Acet–a–napthylamide, 5. Acet–b–napthylamide.

6. Both the potassium and sodium derivatives were crystalline. The sodium derivatives did not melt even up to 280° C. They charred and decomposed at the high temperature. Some of the potassium derivatives, however, did have a definite melting point, (K—Acetanalide 85°C, K—acet–o–toluidide 95°C, and K—acet-p–toluidide 130°C).

From the above observations we have come to the conclusion that the formation of potassium and sodium derivatives has proceeded in two steps as under :—

$$\begin{tikzcd}
Ar.\,NH.\,CO.\,CH_3 \arrow[r] & Ar.\,N:COH.\,CH_3 \arrow[d] \\
 & Ar.\,N:COM.\,CH_3
\end{tikzcd}$$

($Ar = C_6H_5, C_6H_4CH_3$ etc. and $M = Na$ or K), thus proving that the inactivity towards formaldehyde is due to steric hindrance.

The following grounds have led us to the above conception of the whole reaction :—

1. The reactions with sodium and potassium are not vigorous at ordinary temperatures showing that the usual constitution is $Ar.NH.CO.CH_3$.

2. The acyl derivatives do not give any colouration with $FeCl_3$ even after a long time, thus showing that enolic constitution is out of question.

3. They decolourise bromine water slowly.

4. They decolourise $KMnO_4$ gradually.

The reaction with bromine water and $KMnO_4$ is very slow, especially in the case of acet-a-napthylamide, the reaction is slower than in the case of other compounds.

All this evidence tends to prove that the $N:COH$ group is not there from the beginning; but it has come into being slowly, *i.e.*, with the progress of the reaction.

Another reason to believe that the reaction proceeds as stated above is as under:—

Diphenylamine $C_6H_5NHC_6H_5$ was allowed to react with sodium and potassium in the same way as the amides mentioned above. But there was no reaction, the original compound *i.e.* diphenylamine being obtained back quantitatively. There was no decrease in the weights of sodium and potassium taken for the reaction. This proves that the $-NH-$ group alone is not able to form sodium and potassium compounds by the hydrogen atom being replaced by the metal. A- CO -group is also necessary in the adjacent position which can provide the necessary opportunity for the formation of a group $N:COH$. If the hydrogen atom from the $-NH-$ group could be replaced directly by the metal there was no reason why diphenylamine should not form sodium and potassium compounds like acetanalide etc.

We do not, however, hold that our conclusions are final; they may need modification or even correction, if evidence to the contrary is available. Further work in this direction is contemplated to be carried out, the present plan being the study of the action of sodium and potassium on compounds containing the- $NH-$ group either with a - $CO-$ group in the vicinity or without it.

EXPERIMENTAL

I.—*Potassium derivatives*

(i) *Potassium acetanalide*

Acetanalide was dried over P_2O_5 by keeping it, a little over its m. p. for four hours. In a flask about 40 c. c. of dry toluenee (dried by boiling with metallic sodium) were taken. To it dry acetanalide (1·35 gm.) was added and completely dissolved. To the solution, then, potassium (0·39 gm.) was added. The flask was heated under reflux.

After about twenty minutes a white apparently gelatinous mass began to separate. The heating was continued for fourteen hours. The mixture was filtered hot and the solid mass obtained on the filter paper was washed with dry hot toluene several times. It was then dried over P_2O_5 under reduced pressure and at 65°C.

The product is a white crystalline mass insoluble in most of the organic solvents such as benzene, toluene, xylene, ether and petroleum ether. Water decomposed it into acetanalide and alkali quantitatively so that this reaction could be used for the estimation of potassium in the compound, volumetrically. M.P. 85°C. [Found *K*, 22·34% and 22·32% (estimated as K_2SO_4), and, 22·03% (volumetrically); *N*, 8·13%. C_8H_8ONK requires *K*, 22·54%, *N*, 8·09%.]

(ii) *Potassium acet-o-toluidide*

It was prepared as in the above case. The quantities of acet-o-toluidide and potassium taken were 1·49 gm. and 0·39 gm. respectively.

It is a white crystalline substance insoluble in most of the organic solvents as before. Water decomposed it into acet-o-toluidide and alkali quantitatively. [Found :—*K*, 20·41% (estimated as K_2SO_4 and 20·19% (volumetrically); *N*, 7·46%. $C_9H_{10}ONK$ requires *K*, 20·85%; *N*, 7·48%]. M.P. 95°C.

(iii) *Potassium acet-p-toluidide*

It was prepared in the same manner as the o compound. The quantities of acet-p-toluidide and potassium taken were 1·49 gm. and 0·39 gm. respectively. The reaction in this case was very slow. The compound began to separate slowly after two hours heating under reflux. After fourteen hours heating the total yield obtained was also low as compared to others.

It is a white crystalline mass insoluble in most of the organic solvents as before. Water decomposed it into acet-p-toluidide and alkali quantitatively as in the above two cases. M.P. 130°C. [Found *K*, 20·62%, 20·50% (estimated as K_2SO_4) and, 20·69% (volumetrically); *N*, 7·54%. $C_9H_{10}ONK$ requires *K*, 20·85%; *N*, 7·48%.]

(iv) *Potassium acet-a-napthylamide*

It was prepared as in the above cases. The quantities of acet-a-napthylamides and potassium taken were 1·85 gm. and 0·39 gm. respectively.

It is a white crystalline mass insoluble in most of the organic solvents. Water decomposed it into acet-a-napthylamide and alkali quantitatively as before. It did not melt even upto 280°C. but charred and decomposed at the high temperature. [Found *K* 17·25%, 17·37%, 17·49% (estimated as K_2SO_4) and 17·23% (volumetrically); *N*, 6·20% $C_{12}H_{10}ONK$ requires, *K*, 17·48%; *N*, 6·27%].

(v) *Potassium acet-b-napthylamide*

It was prepared as in the above cases. The quantities of acet-b-napthylamide and potassium taken were 1·85 gm. and 0·39 gm. respectively.

It is a white crystalline mass insoluble in most of the organic solvents. Water decomposed it into acet-b-napthylamide and alkali quantitatively as in the other cases. It did not melt even upto 280°C. but charred and decomposed at the high temperature. [Found K 17·42%, 17·29% 17·56% (estimated as K_2SO_4) and 17·26% (volumetrically); N 6·18%. $C_{12}H_{10}ONK$ requires, K, 17·48%; N, 6·27%]

II. SODIUM DERIVATIVES

(i) *Sodium acetanalide*

In a flask, about 40 c. c. of toluene (dried by boiling with matallic sodium) were taken. To it dry acetanalide (1·35 gm.) was added and completely dissolved. To the solution sodium (0·23 gm.) was added. The flask was then heated under reflux. After about half an hour a white apparently gelatinous mass began to separate. The heating was continued for about twelve hours. The mixture was then filtered hot. The white mass obtained on the filter paper was again boiled with a fresh quantity of dry toluene for about an hour. It was filtered hot and the above process repeated two times more. It was then dried over P_2O_5 under reduced pressure and at 60°C.

The product obtained is a white crystalline mass insoluble in most of the organic solvents such as benzene, toluene, xylene, ether and petroleum ether. Water decomposed it into acetanalide and alkali quantitatively, so that this reaction could be used for the estimation of sodium in the compound volumetrically. It did not melt even upto 280° C. but charred and decomposed at the high temperature. [Found Na, 14·21% (estimated as Na_2SO_4) and 14·33% (volumetrically); N, 8·75%. C_8H_8ONNa requires Na, 14·64%, N, 8·91%.]

(ii) *Sodium acet-o-toluidide*

It was prepared as in the above case. The quantities of the acet-o-toluidide and metallic sodium taken were 1·49 gm. and 0·23 gm. respectively. After about half an hour a white substance began to separate. After twelve hours boiling under reflux it was filtered off. It was again boiled with a fresh quantity of dry toluene for about an hour and filtered off. The process was repeated two times more, each time taking a fresh quantity of toluene.

It is a white crystalline mass insoluble in most of the organic solvents as before. Water decomposed it quantitatively into acet-o-toluidide and alkali. It did not melt even upto 280°C. but charred and decomposed at the high temperature. [Found *Na*, 13·11% (estimated as Na_2SO_4) and 13·53% (volumetrically); *N*, 8·56%. $C_9H_{10}ON\ Na$ requires *Na*, 13·45%; *N*, 8·18%).

(iii) *Sodium acet-p-toluidide*

It was prepared as in the above case. The quantities of acet-p-toluidide and sodium taken were 1·49 gm. and 0·23 gm. respectively. After about twelve hours heating it was filtered off. The white mass obtained was again boiled as before, three times more, each time taking a fresh quantity of dry toluene. The reaction in this case is very slow.

It is a white crystalline mass, insoluble in most of the organic solvents as before. Water decomposed it quantitatively just like the other sodium and potassium derivatives. It did not melt even upto 280°C. but charred and decomposed at the high temperature. [Found *Na*, 13·22% (estimated as Na_2SO_4) and 13·30% (volumetrically); *N*, 8·28%. $C_9H_{10}ON\ Na$ requires *Na*, 13·45%; *N*, 8·18%].

(iv) *Sodium acet-a-napthylamide*

It was also prepared as in the above cases. The quantities of acet-a-napthylamide and sodium taken were 1·85 gm. and 0·23 gms. respectively.

It is a white crystalline mass insoluble in most of the organic solvents. Water decomposed it as in the other cases. It did not melt even upto 280°C. but charred and decomposed at the high temperature. [Found *Na*, 10·85% (estimated as Na_2SO_4), and 10·98% (volumetrically); *N*, 6·83%. $C_{12}H_{10}\ ON\ Na$ requires *Na*, 11·11%; *N*, 6·76%.)

(v) *Sodium acet-b-napthylamide*

It was also similarly prepared as the above derivatives. The quantities of acet-b-napthylamide and sodium taken were 1·85 gm. and 0·23 gm. respectively.

It is a white crystalline mass insoluble in most of the organic solvents. Water decomposed it quantitatively just like other sodium derivatives. It did not melt even upto 280° C. but charred and decomposed at the high temperature. [Found *Na* 10·85% (estimated as Na_2SO_4) and 11·28% (volumetrically); *N* 6·54%. $C_{12}\ H_{10}\ ON\ Na$ requires *Na*, 11·11%; *N*, 6·76%].

A STUDY OF THE OIL FROM THE NIGER SEED (GUIZOTIA ABYSINICA)

By

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A biochemical study of the development of oil in the Niger Seed was done by the authors and has already been sent for publication to the *Indian Journal of Agricultural Science.* The present paper deals with the study of the oil as obtained in the resting condition of the

The seed of the Niger plant in the resting condition is glistening black in colour. Its length is 2 to 2·5 mms. and each seed weighs about 3 mgms. The seed contains 40% of oil. The cold pressed oil is bright golden yellow in colour.

This study was taken with a view to determine the chemical nature of the oil. The physical and the chemical constants as also the further study referred to in this paper give a clear idea about the nature of the oil and the various uses to which it can be put.

PHYSICAL CONSTANTS

The cold pressed oil as obtained from the *ghani* was allowed to settle and then filtered through filter paper. This removed the water and the mucilage from the oil. The oil thus obtained was used in all the work detailed in this paper.

Specific Gravity.—The Sp. gravity was determined by both the Sp. gravity bottle and the Westphal's balance.

Sp. gravity bottle method		Westphal's Balance	
0·9250	at 15·5° C	0·9256	at 15·0° C
0·9157	at 28·6° C	0·9160	at 28·6° C

Refractive Index.—The refractive Index was determined by means of the Abb's Butyro-refractometer. The reading was taken at three different temperatures.

Temperature °C	Scale division	(N_d) corresponding R. Index.
40	60·4 to 60·5	1·4662
36	62·6	1·4675
28	67·1	1·4678

Optical Activity.—The oil is optically inactive when fresh. But when allowed to polymerise by keeping the fresh oil it shows slight activity. Thus when the rancidity or the polymerisation had proceeded to 21·4 mgms. *KOH* per gram of oil the sample showed a rotation of 3·4°.

Tintometer Readings.—J. V. Loviband's tintometer was used to determine the colour of the oil. In one inch thickness the oil requires 40 to 42·5 yellow and 1·2 to 1·4 of red.

Melting and Solidifying Points.—The oil when cooled becomes viscous at −7·5° C and solidifies at −8·5 to −9·0° C and begins to be viscous at −7·0° C and a clear liquid at about −6° C.

CHEMICAL CONSTANTS

Free Acidity.—The number of milligrams of KOH required to neutralise the free acids of the oil were determined by titration in an ether alcoholic solution of the oil.

The Fresh oil—unfiltered requires 9 to 10 mgms. KOH per gram of oil.
The fresh oil—settled and filtered: 6·2 „ „ „ „ „
The oil heated to 110° C and then filtered: 3·8 „ „ „ „

Saponification Value.—The number of milligrams of KOH required to neutralise the combined and free acids of the oil by saponifying the oil with $N/2$ alcoholic KOH was found to be 194·6.

Acetyl Value.—The number of miligrams required to neutralise the volatile acids of the oil after the replacement of the hydroxy groups by acetyl by boiling the oil with acetic anhydride was found to be 24·1. The method used was as described by Lewkowitsch (1897) and E. André (1921).

Reichert-meissl Value and the Polenski Number.—5 grams of the oil were saponified by KOH in 20 cc. glycerine and then the soaps dissolved in hot water and acidified with sulphuric acid and distilled. The number of ccs. of $N/10$ KOH required to neutralise the volatile soluble (R. M.) and the insoluble acids of the distillate was found out. It was very small being

R. M. Value	1·2 ccs. KOH
Polenski Figure	0·2

Unsaponifiable Matter.—The oil even though filtered contains 0·3 to 0·6 per cent of an unsaponifiable material which can be extracted from the soaps formed by hydrolysing the oil with KOH by means of petroleum ether.

Iodine Value.—The oil or the free acids of the oil absorb large amounts of halogens. The amount of Iodine that the oil can absorb was determined by the Wij's modified method of Hubl's process.

100 grams of oil can absorb 126·4 grams of Iodine (Wij)
79·8 grams of bromine

THE INSOLUBLE FATTY ACIDS

The oil was saponified by means of alcoholic potash and the soaps were dissolved in large quantities of water and the free fatty acids liberated by acidifying with hydrochloric acid. The insoluble (in water) acids were collected together and were then dried over calcium-chloride in a vacuum dessicator.

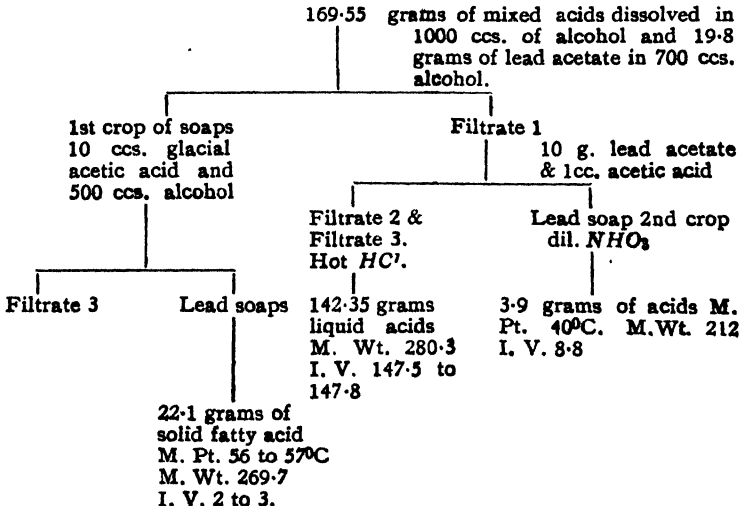
The percentage of the fatty acids was found to be 94·2.

The acids thus obtained were of a pale yellow colour; and on standing separate into two layers, the lower of solid and the upper of liquid acids.

They have a titre of 18 to 20° C.
The M. Pt. is 21°C (when allowed to stand at room temperature)
The neutralisation value is 202·8 mgms. *KOH* per gram of acids.
The mean molecular weight 275·6 (calculated from above).
The Iodine value 134·1 (Wij's Method).

The combined solid and liquid fatty acids were then separated into liquid (hence unsaturated) and solid (saturated) fatty acids by the Twitchell's method. The separation accomplished by this method and that by the lead-salts-ether method correspond quite fairly with each other.

Twitchells Method.—The acids were dissolved in 92·8 % alcohol and neutralised exactly with alcoholic *KOH*. To this was then added a solution of magnesium acetate in alcohol acidified with acetic acid. The quantity of magnesium acetate added was enough to precipitate 20 per cent of the total fatty acid taken. The mixture boiled for 15 minutes and then left overnight to cool. The precipitated magnesium salts were filtered off and from the salts the free acids liberated by means of hydrochloric acid. The free solid acids thus obtained were submitted to the same process once more. From the alcoholic filtrates and washings the liquid fatty acids were recovered.



169·55 grams of mixed acids dissolved in 1000 ccs. of alcohol and 19·8 grams of lead acetate in 700 ccs. alcohol.

1st crop of soaps 10 ccs. glacial acetic acid and 500 ccs. alcohol

Filtrate 1 10 g. lead acetate & 1cc. acetic acid

Filtrate 2 & Filtrate 3. Hot HC'.

Lead soap 2nd crop dil. NHO_3

Filtrate 3

Lead soaps

142·35 grams liquid acids M. Wt. 280·3 I. V. 147·5 to 147·8

3·9 grams of acids M. Pt. 40°C. M.Wt. 212 I. V. 8·8

22·1 grams of solid fatty acid M. Pt. 56 to 57°C M. Wt. 269·7 I. V. 2 to 3.

Thus in all 169·55 grams of acids gave
22·1 grams of solid acids,
3·9 ,, ,, ,,
142·3 ,, liquid and hence unsaturated acids.

168·33 Total

Hence the percentages are :—
84·9 % unsaturated acids.
14·9 % saturated acids.

The Solid Acids.—The saturated acids as obtained above were then turned into their methyl esters. The acids were dissolved in three times their weight of methyl alcohol and then saturated with dry hydrochloric acid gas. The solution was then refluxed on a sand bath for 8–10 hours. The methyl esters were then recovered from the solution and dried over anhydrous magnesium sulphate as usual. [Armstrong and Allen (1929).] These esters were then distilled at 1 to 16 mm. pressures into six different fractions.

TABLE No. I

Fraction No.	Pressure in	Temperature in O^{0}C	Weight of esters in grams
1.	16 to 18	upto 170	1·3
2.	12 to 14	172 to 198	3·1
3.	,,	198 to 200	17·6
4.	,,	200 to 208	12·1
5.	,,	208 to 240	12·6
6.	,,	Residue	5·4
		Total	51·1

The free acids were then obtained from the esters by hydrolysis with *KOH*. The different fractions of acids thus obtained were then further separated into individual acids by fractional crystallisation of the magnesium salts.

A weighed amount of the free acids was taken and just neutralised with *KOH* in alcoholic solution and magnesium acetate solution made strongly acid with a little acetic acid. The whole boiled for half an hour and then slowly cooled.

The amount of magnesium acetate added was sufficient only to precipitate about 15% of the total acids taken. Thus only the acids of the higher molecular weights were first precipitated and the lower acids remained in solution. Thus in an experiment 96 grams of acids—the total of the six fractions given in the above table—were separated into the following :—

TABLE No. II

Fraction	d_1	d_2	d_3	d_4	d_5	d_6	Total
Mean Mol. Wt.							
C1. 200 to 228	0·9	1·4	0·1				2·4
C2. 250 to 270	0·4	4·4	27·1	15·1	10·0		57·0
C3. 275 to 290			5·7	7·0	13·1	7·35	43·05
C4. above 290					0·4	2·8	3·25
Total Quantity found	1·3	5·8	32·9	22·1	23·5	10·15	95·7
,, ,, lost	0·2	0·0	0·5	1·2	0·5	0·25	2·7

d refers to the distillation fraction number in the last table while C refers to crystallisation fraction. From each of the crystallisation fraction the free acid was again obtained and the melting point and the mean molecular weight of the acid determined from the corresponding silver salt. Similarly the C2 and C3 fractions were submitted to the Hehner and Mitchell's process of stearic acid determination. This gave the approximate amount of stearic acid in each fraction. From this weight and assuming that the C1 fraction practically consists of lauric, myristic and palmitic acids the percentages of the various acids in the different fractions was calculated. It is approximately as

TABLE No. III

Fraction	Percentage composition of the fractions						Total
	d_1	d_2	d_3	d_4	d_5	d_6	
Lauric & Myristic	69·6	24·0	0·3				93·9
Palmitic	30·2	76·0	81·1	65·0	41·5		293·8
Stearic			17·1	30·0	54·5	70·0	171·6
Arachidic & Lignoceric					1·6	27·0	28·6
Unsaturated acids	1·6	0·0	1·5	4·8	2·0	2·9	12·8
Total ...	101·4	100·0	100·0	99·8	99·6	99·9	600·8

From this table and the figures given in Table No. II the percentages were calculated on the total fatty acids obtained in the Twitchell's method. The approximate percentages of the individual acids in the solid portion appear to be the following :—

Lauric and Myristic	2·42	per cent
Palmitic	57·57	„
Stearic	33·48	„
Arachidic and Lignoceric	3·28	„
Total...	96·75	
Unsaturated acids	3·25	„

All making a total of 14·9% of the total fatty acids of the oil.

UNSATURATED ACIDS

After the removal of the solid acids as insoluble magnesium salts the unsaturated fatty acids were recovered from the alcoholic washings and the filtrates. The liquid acids after the removal of alcohol and drying on anhydrous magnesium sulphate are pale yellow in colour. The mean molecular weight is 280·3 and the Iodine value 147·5. A portion of these acids was turned into their methyl esters and distilled at 2 to 3 mm.; but it was not possible to separate the individuals as a constant boiling mixture is formed when about 25 to 30% of the esters were distilled off. The composition of the distillate at this stage is approximately 50% oleic and 50% linolic acids. Thus :—

TABLE NO. IV

100 grams of the esters of unsaturated acids distilled at

Fraction	Boiling point	Pressure	Weight	Iodine V	S. V.
	°C	mm.	grams	(contains alcohol etc.)	
1	160 to 168	5 to 7	6·8		
2	168 to 170	3 to 5	30·2	169·76	191·7
3	172 to 180	„	20·1	129·9	191·3
4	upto 184	„	22·3	128·6	191·3
5	Residue	„	21·6	123·8	191·6
		Total	100·0		

Fraction 2 is nearly pure linolic acid ester. The theoretical I. V. of methyl linoleate is 171·9 and of the fraction is 169·76. Similarly the molecular weight of the methyl ester would be 292·0 while that of the fraction is 292·07.

The next three fractions are practically a half to half mixture of linolic and oleic esters; (for as will be shown presently there is no linolenic acid present in oil.) Hence a fractionation of the acids by distillation is not possible in this case.

BROMINATION OF THE UNSATURATED FATTY ACIDS

The bromination of the fatty acids was tried by all the three methods described by (1), Lewkowitch (1924), Suzuki (1921) and (3) A. Gammel (1914).

The fatty acids do not yield any insoluble hexabromide of linolenic acid in ethyl ether whether the bromination is carried in dry or moist ether and with or without glacial acetic acid. As will be seen later the acids yield the various modifications of the linolic acid and these in no case show any higher percentage of bromine than that calculated for the linolic acids. Hence the linolenic acid is most probably absent. So the actual quantitative work was carried in a modified form of Takashahi's (1919) method.

The liquid fatty acids (10·12 grams) were dissolved in 250 ccs. of petroleum ether. This solution was well cooled in ice and then a cold solution of bromine (10 grams in 100 ccs.) of the same solvent was slowly added with constant stirring. After the complete addition the mixed solution was kept overnight in an ice box. A precipitate of (8·63 grams) of alpha tetra-brom-stearic acid was obtained which was filtered and washed with cold petroleum ether. On recrystallisation the bromo-acid melts at 114·2°C and has a bromine content of 53·21% (Theo.–53·33). Hence this precipitate would correspond to 4·6 grams of linolic acid in the 10·12 grams of the original acids. From the filtrates and washing after the removal of the excess of bromine with sodium-thiosulphate and a little concentration a second crop (3·42 grams) of mixed solid bromoacids was obtained. After recrystallisation from cold petroleum ether this fraction gave 1·5 grams of the alpha modification (corresponding to 0·8 grams of linolic acid) of tetra-bromstearic acid were obtained; and 1·91 grams of the beta and delta modifications of the linolic acid were obtained. These are fairly soluble in petroleum ether. This portion melts at 60°C and has a bromine percentage of 53·2%. When this fraction is being recrystallised from petroleum ether two sorts of crystals are obtained. On the sides of the flask long needle-like crystals are formed while at the bottom silky flakes greyish white in colour are obtained; but it was not possible to separate these two.

Finally, on complete removal of the petroleum ether from the mother liquors a red thick viscous oil was obtained. This oil is soluble in both pure alcohol and in an alcoholic solution of calcium chloride. It contains 38·6% per cent of bromine, hence it seems that it also contains some of the gamma-modification of the tetra-brom-stearic acid; because the di-brom-stearic acid would contain only 36·2% of bromine. The gamma-modification as such could not be separated as described by Smith and Webb (1927). The weight of the oil obtained was 7·2 grams. Thus:—

On bromination 10·12 grams of the unsaturated Acids gave

Ppt.1—	8·63	grams of alpha-tetra-brom-stearic acid.
Ppt.2—	1·5	„ „ „
and		
	1·91	„ of beta and delta „
Frac.3—	7·9	„ of a red oil consisting of a mixture of 4·14 grams of tetra-brom and 3·06 of di-brom-stearic acids.
	19·24	„ Total. (Expected 19·52 grams as the acids have an iodine value of 147·4).

Hence the composition of the unsaturated acids is

36·4% oleic

63·6% linolic out of which

46·7% is alpha and

16·9% of other modifications.

Hence summing up the total insoluble fatty acids are

Solid (saturated)		per cent
14·6%	Lauric and Myristic	3·35
	Palmitic	8·41
	Stearic	4·89
	Arachidic and Lignoceric	0·48
Liquid (unsat.) 85·4	Unsaturated	0·47
	Oleic	31·06
	Linolic	54·34
	Total	100·0

BROMINATION OF THE OIL

The bromination of the oil was carried on the lines as described by Suzuki and Yakohama (1927). Preliminary experiments showed that the oil does not contain any glycerides which on bromination would yield insoluble bromo-glycerides insoluble in ethyl ether. Hence further work was carried on using petroleum ether as the solvent.

50·4 grams of oil were dissolved in 700 ccs. of the petroleum ether and the solution well cooled in ice. 50 grams of bromine in 300 ccs. of the solvent similarly cooled were then added to the solution of oil with constant stirring. The addition was carried on very slowly. Soon a yellow precipitate of brominated glycerides separated out. The whole was well shaken and left overnight in an ice box. The next day the precipitated glycerides were filtered, washed with more petroleum ether and dried. (Fraction 1. weight —3·9 grams.)

The filtrate and washings were then treated with sodiumthiosulphate solution to remove the excess of bromine and then the etherial solution concentrated a little and cooled in ice; a semi-viscous solid was obtained, weighing 28·6 grams. (Fraction 2.)

On further concentration the mother liquor yielded 29·2 grams of a viscous liquid which is sparingly soluble in petroleum ether and becomes more and more insoluble as it is kept. (Fraction 3.)

Finally on complete removal of the solvent a red viscous oil was obtained, weighing 28·8 grams (Frac. 4). Thus in all the 50·4 grams of the oil gave

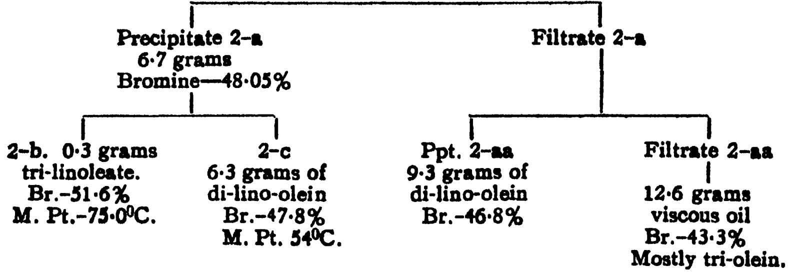
Fraction 1.	3·9 grams
Fraction 2.	28·6 „
Fraction 3.	29·2 „
Fraction 4.	28·8 „
Total	90·5 „

Total 90·5 „ expected 90·4 grams of the brominated product as the iodine value of the oil was 126·4.

Fraction 1.—This fraction when recrystallised from petroleum ether gave a grey white powder which melts sharply at 76·5°C. It is sparingly soluble in warm petroleum ether but very soluble in ethyl ether. It is sparingly soluble in methyl and ethyl alcohols. It has a bromine percent of 51·9%. On hydrolysis with hydrochloric acid in methyl alcohol solution the solid yields a solid bromo acid which melts at 110°C and corresponds to tetra-brom-stearic acid. The melting point and the bromine percent show that the solid fractions most probably tri-linoleo-bromide with the linolic acid in the alpha modification (Theoretical Br. % – 52·3 found 51·90). The total weight of the fraction *viz.* 3·9 grams correspond to 1·85 grams of the original oil *i. e.* the percentage would be 3·7.

Fraction 2.—A viscous semi-solid, 28·6 grams. The bromine percent after the complete removal of the solvent is 46·8%. The fraction was dissolved in warm petroleum ether and the solution cooled to about – 4°C in a freezing mixture and after stirring for a while left there for a few hours. Thus a solid precipitate was obtained weighing 6·7 grams. This was filtered and washed with a little cold petroleum ether. This precipitate on recrystallisation was separated into portions; one weighing 0·3 and the other 6·3 grams. The first is the tri-linoleate having a bromine content of 51·6 percent. The other portion had only 47·8 percent of bromine and melted at 54 to 55°C. Hence this fraction seems to be di-lino-oleo-bromide. (Theoretical Br. – 47·6%). From the original filtrate on concentration and cooling a solid weighing 9·3 grams was obtained having a bromine percent of 45·8 and melting at 50°C. The melting point went to 54 to 55°C on repeated crystallisations. From the concentrated mother liquor a viscous red oil was recovered which had a bromine content of 45·0%. This could not be further separated. The alcoholic solution of calcium-chloride of different strengths did not help the separation as described by Suzuki and Yakohama (1927) for other oils.

Thus out of the whole 28·6 grams of Fraction 2 we get



Each of the fractions was first hydrolysed by hydrochloric acid in methyl alcohol and the bromoacids thus obtained de-brominated and the iodine-value of the acid again determined. Thus the last 2–aa filtrate yielding 12·6 grams of bromoglyceride gave a liquid acid which on de-bromination had an iodine value of 85·6. Hence it appears that there is no linolic or saturated acid present; and the fraction is pure tri-olein.

Fractions 3 and 4 were submitted to the same treatments of separation but no definite conclusions could be obtained. Hence it appears that the oil contains the following separable products :—

3 to 4 % Tri-olein giving a solid bromo-derivative M. Pt. 76·5°C.

20 to 25 % Di-lino-olein giving a solid bromo-derivative melting at about 54 to 56°C.

The oil when oxidised with potassium permanganate in acetone solution does not yield any fully saturated glycerides and is completely oxidised. Hence no fully saturated glyceride is present in the oil.

On hydrogenation the oil gives a solid white fat melting at 62°C with an iodine value of 34. The hydrogenation proceeds normally and no iso-oleic acid could be detected in the course of hydrogenation.

The drying property of the oil :—The oil can be made to dry within 20 hours by heating the oil at 240°C for 2 to 3 hours with 2·4% of a drier made of Manganese resinate and lead oleate.

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4. Lewkowitch *Technology of Oils and Fats*, Vols. 1 to 3, (1924)

5. Suzuki (*Proc. Imp. Ac. Sc. Tokyo*, 1921).
Suzuki and Yakohama (Ibid. 1927, 3, 526 et sec).

6. Takashahi.

7. Twitchell (*J. A. C. S.*, 1895, 17, 289 and *Analyst*, 1900, 25, 33).

8. Wij (*J. S. C. I.*, 1898, 17, 698 and *Analyst*, 1900, 25, 33).

A general summary of the methods used in the analysis of oils and fats appears in *J. S. C. I.*, 1929, 48, 9,212— *Recent Advances in our knowledge of the structure of the more common fats.*

VIOLIT, AN OPEN CHAIN ANALOGUE OF MUREXIDE

By

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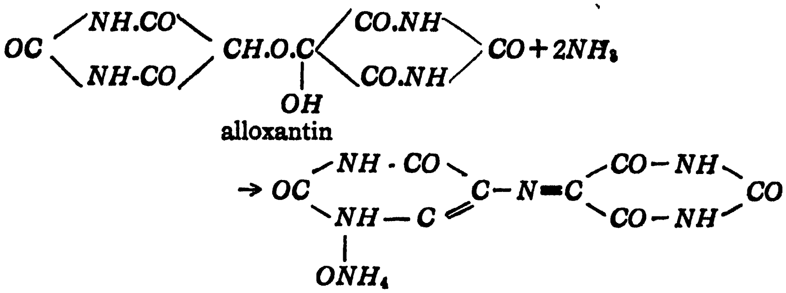
The production of murexide by the action of aqueous ammonia on alloxantin is a well known reaction and is represented by the equation:

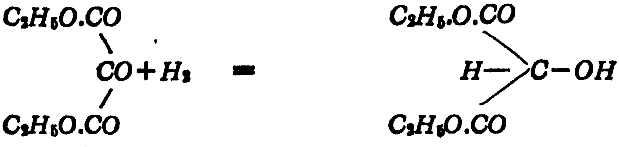


alloxantin

murexide

The deep colour of murexide is probably to be explained by the peculiar arrangement of the *CO* and *NH* groups in the two rings in addition to the introduction of the alternate single and double bonds between the two rings. In view of the colourless appearance of both alloxan and alloxantin, it would seem that the latter factor is the more important in the production of the deep colour of murexide. (Hantzsch and Robinson, *Berichte*, 1910, *43*, 92; Biltz, *Annalen*, *404*, 198.)

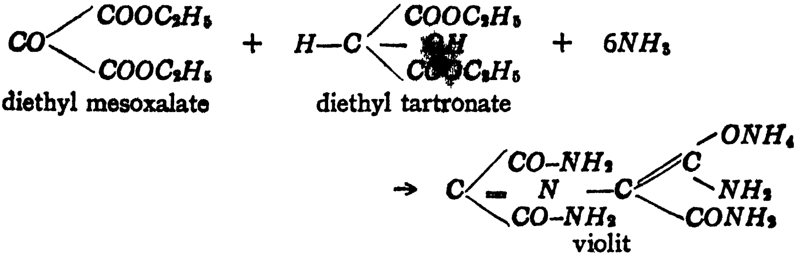
It was therefore thought important to see if coloured compounds of the nature of murexide could not be obtained by using open chain analogues of alloxantin and treating them with ammonia. The compound chosen for this purpose was mesoxalic ester. It differs from alloxan inasmuch as it is directly reduced to diethyl tartronate and does not produce an intermediate compound corresponding to alloxantin:



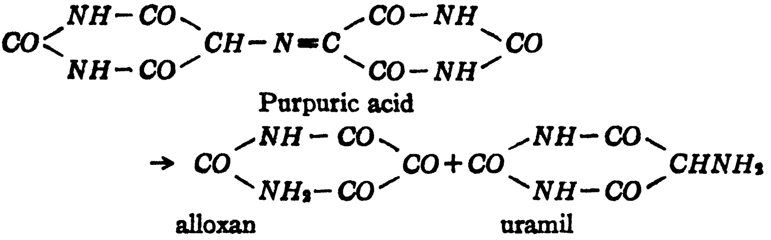
mesoxalic ester

tartronic ester.

If however molecular quantities of diethyl mesoxalate and diethyl tartronate are taken and mixed with an excess of aqueous ammonia a deep violet coloured crystalline powder is obtained, for which the name " violit " is proposed. Analogous to murexide, the formation of violit may be represented as :



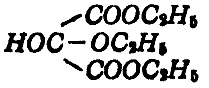
The same compound is obtained by allowing aqueous ammonia to act upon a mixture of the diamides of mesoxalic and tartronic acids, which goes to confirm the above configuration suggested for violit. The similarity in the chemical behaviour of murexide and violit is also brought about by their reaction with acids. The free acid derived from murexide being very unstable, it breaks up according to the equation : (Gregory, *Ann.*, *33*, 334.)



Violit also behaves in exactly the same way and is at once decolourised by acids. The sodium salt corresponding to violit has also been prepared but is not so deeply coloured as violit.

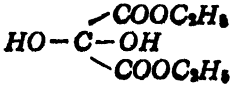
EXPERIMENTAL

Diethyl mesoxalate was prepared by the dehydration of its crystalline hydrate, diethyl oxomalonate, with phosphorus pentoxide according to the method of Curtiss and Spencer (*J. Am. Chem. Soc.*, 1909, *31*, 1054). The yellowish green diethyl mesoxalate (10 cc.) was dissolved in absolute alcohol (20 cc.) and reduced by palladium catalyser precipitated on barium sulphate (2 gr.) according to the method of Schmidt (*Berichte*, 1919, *52*, 409; also, Zimmer and Co., *D. R. P.* 252136 of 1912). On mixing the ester with alcohol, it is instantaneously decolourised and a considerable amount of heat is produced. This is due to the formation of an alcoholate



$$HOC{-}OC_2H_5\begin{array}{l}\nearrow COOC_2H_5\\ \\ \searrow COOC_2H_5\end{array}$$

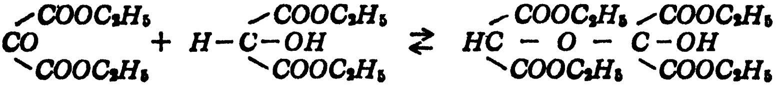
corresponding to the oxomalonic ester.



$$HO{-}C{-}OH\begin{array}{l}\nearrow COOC_2H_5\\ \\ \searrow COOC_2H_5\end{array}$$

There is however no difficulty in the reduction of this alcoholate, when it is shaken with the catalyser at ordinary temperature in an atmosphere of pure hydrogen. For this purpose, the Kipp was connected with a wash bottle containing permanganate solution (in order to remove possible traces of hydrogen sulphide, which would destroy the activity of the catalyser) and then connected with a wide tube containing the mixture to be reduced. This latter is fixed on to a shaking machine. The reduction is complete in 7 to 8 hours and the yield of diethyl tartronate was 75 p. c. of the theory. Reduction at the temperature of boiling alcohol or the use of other solvents was found to give very poor yields.

Equimolecular quantities of pure diethyl mesoxalate and diethyl tartronate were then mixed together in order to see if an intermediate compound corresponding to alloxantin could be isolated. This was not found possible, as even boiling under reflux does not completely decolourise the mesoxalic ester. That there is a certain amount of combination between the two is however clear from a molecular weight determination of the mixture in benzene. The values obtained (242 and 249 in two experiments) show that probably an equilibrium of the following nature is present in the mixture. (mol. wt. of mesoxalic ester is 174 and that of tartronic ester is 192.) :



$$CO\overset{\diagup COOC_2H_5}{\underset{\diagdown COOC_2H_5}{}} + H-\overset{\diagup COOC_2H_5}{\underset{\diagdown COOC_2H_5}{C}}-OH \rightleftarrows H\overset{\diagup COOC_2H_5}{\underset{\diagdown COOC_2H_5}{C}} - O - \overset{\diagup COOC_2H_5}{\underset{\diagdown COOC_2H_5}{C}}-OH$$

An excess of ammonia was then added to the mixture and the brownish coloured solution was kept for 24 hours at ordinary temperature. At the end of this period, the colour had changed to deep violet red, without however any solid having separated out. The solution was therefore concentrated under reduced pressure and finally dried in a vacuum desiccator over solid potassium hydroxide. The violet crystalline powder that remained behind was extremely hygroscopic and was converted into a sticky mass immediately on exposure to air. It was washed with pyridine in order to remove any traces of mesoxalic or tartronic amides and the pyridine removed by gentle heating in vacuum. The residue was then micro-analysed with the following results :

3·639 mg. gave 3·98 mg. CO_2 and 1·82 mg. H_2O.

2·391 mg. gave 0·436 cc. of N_2 at 21·5° and 748 mm.

Found : % C 30·9, H 5·6, N 36·1.

Calculated for $C_6H_{12}O_4N_6$: C 31·04, H 5·2, N 36·2.

If a methyl or ethyl alcoholic solution of ammonia is used instead of an aqueous solution, a separation of yellowish crystals, of the amides takes place. These could be separated and identified by a determination of their molecular weights. Water thus seems to be essential to the formation of violit.

If a dilute solution of hydrochloric acid is added to a solution of violit, it is at once decolourised and the salts of the amides of mesoxalic and tartronic acids are produced. If ammonia is again added until the solution is alkaline, the violet colour returns owing to the reformation of violit.

On treatment with dilute caustic soda and gentle warming the sodium salt is formed in solution as is indicated by the slightly paler colour as compared with a solution of violit of the same concentration. It was not however possible to isolate the sodium salt in the pure condition.

Further work, especially in connection with the comparison between the absorption spectra of violit and murexide is in progress and will be published in due course.

A NOTE ON LACTONE FORMATION IN SUNLIGHT

By

D. B. LIMAYE

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Ciamician and Silber (*Ber.*33,2911–1900) have shown that benzophenone when exposed to sunlight in absolute alcoholic solution, forms benzpinakone in good yield, the alcohol being oxidised to aldehyde. Similar reactions have been studied using other ketones and alcohols, by other chemists. (Cf. *Cohen Rec.* 39,243).

It seemed of interest to investigate the influence of substituent groups such as "*COOH*", "*OH*" etc. in place of one of the hydrogen atoms of the phenyl group in benzophenone, on the general course of the reaction.

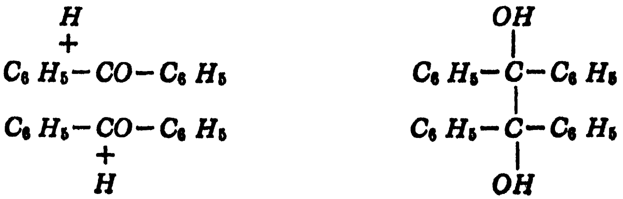
With this point in view experiments had been started using substances containing a Carboxyl group as a substituent.

REDUCTION OF *O*-BENZOYL-BENZOIC ACID

2 gms. of benzophenone Carboxylic acid (ortho) dissolved in 5 c. c. of absolute alcohol were exposed to direct sunlight in a sealed glass tube. In about a week the tube was full of beautiful white crystals, which were removed and washed with alocohol and ether. The dry substance weighed about 1 gm. The main filtrate when again exposed gave a further crop of crystals. For analysis the substance was once more purified by extracting with boiling alcohol. The melting point was 265°–266°C. The elementary analysis gave $C=80\cdot0\%$ $H=4\cdot5\%$ calculated for $C_{28}H_{18}O_4$ $C=80\cdot4\%$ $H=4\cdot35\%$.

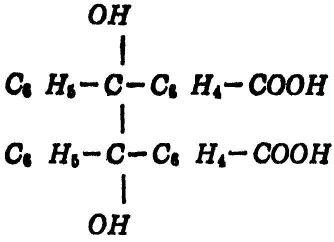
The white solid contained no free carboxyl group. It was not much soluble in alcohol but dissolved in boiling acetic acid. By reference to literature the compound was soon identified with the dilactone of tetraphenyl-dihydroxy-ethane dicarboxylic acid (Ullmann, Annalen, 291,20,1896).

Since benzophenone reacts in sunlight in the sense of the following equation :—



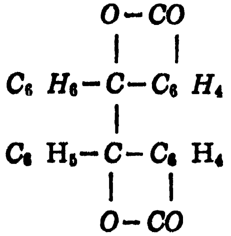
$$\begin{array}{c} H \\ + \\ C_6H_5-CO-C_6H_5 \\ \\ C_6H_5-CO-C_6H_5 \\ + \\ H \end{array} \qquad\qquad \begin{array}{c} OH \\ | \\ C_6H_5-C-C_6H_5 \\ | \\ C_6H_5-C-C_6H_5 \\ | \\ OH \end{array}$$

The carboxylic acid might be expected to give



$$\begin{array}{c} OH \\ | \\ C_6\,H_5-C-C_6\,H_4-COOH \\ | \\ C_6\,H_5-C-C_6\,H_4-COOH \\ | \\ OH \end{array}$$

But the reaction in this case proceeds further with the elimination of 2 molecules of water to form



$$\begin{array}{c} O-CO \\ |\quad\;\; | \\ C_6\,H_6-C-C_6\,H_4 \\ | \\ C_6\,H_5-C-C_6\,H_4 \\ |\quad\;\; | \\ O-CO \end{array}$$

Ullmann had obtained this compound by the action of hydriodic acid under definitely regulated conditions as otherwise the reduction proceeds in other ways giving anthraquinone and anthracene. The method described here, when suitably modified will be a simple way of getting the dilactone. In order to test the applicability of the reaction in other cases, p-toluoyl-o-benzoic acid was exposed to sunlight as described above for two weeks. A compound (melting point 247°–248°C) possessing similar properties was obtained though comparatively slowly,

Analysis gave:—$C = 80{\cdot}3\%$, $H = 5{\cdot}1\%$

Calculated for $C_{30}H_{22}O_4 = 80{\cdot}7\%$ $H = 4{\cdot}9$

This could not be identified with any known compound but by analogy may be taken to possess a similar structure with the dilactone described above.

Acetophenone ortho carboxylic acid gives an apparently similar compound which requires further investigation.

A PLEA FOR THE CREATION OF A POSTGRADUATE DEPARTMENT OF MATHEMATICS IN THE UNIVERSITY

By

Prof. K. R. GUNJIKAR, B. Sc. (Bom.), M. A. (Cantab)

> " And whereas it is necessary to reconstitute the said University to enable it to provide greater facilities for higher education and *to conduct postgraduate teaching and research in all branches of learning, including technology,* . . . . it is hereby enacted as follows :—"
>
> The preamble of the new University Act of 1928

The purpose of this article is to suggest briefly some lines along which the University of Bombay ought to proceed to carry out one of its most important functions, *viz.*, the building up of a strong postgraduate department in Mathematics for teaching and research. While the needs of Mathematics are kept specially in the forefront, it is possible that these suggestions may be of some use to other subjects also.

It may not be amiss to review in the beginning the present position of Mathematics in the University. We need not consider here the work done up to the Intermediate stage, as specialisation in Mathematics begins in the B.A. and the B.Sc. classes. Fortunately up to the stage of the Bachelor's degree examination, there is very little to complain of. The majority of colleges have well qualified lecturers on their staff whose first attention is devoted to the Honours* work in Mathematics; and since as a rule only those students who have a strong liking for the subject go in for it, the classes are generally alert and enthusiastic. We can honestly claim with pride that the standard of Mathematics for the B. A. or the B. Sc. examinations in intensity as well as in extent, is in no way inferior to that in any other Indian University.

Matters are however not at all so satisfactory when we come to the postgraduate stage. It seems to be the general impression that students who have taken the Bachelor's degree require very little further help in their postgraduate studies. This is perhaps true to some extent in subjects like Literature or History, but so far as

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* In the course of this article the term 'lecturers' is used to denote Professors, Assistant Professors and all the other kinds of teachers working in colleges. Similarly the term "Honours work" includes also the Principal Mathematics course for the B. Sc. degree.

Mathematics is concerned it is certainly far from true. The subject has developed to such an extent that a student working without adequate help will take years to prepare for the Master's degree and even then may fail to get through with credit. The course is both difficult and extensive and candidates for the Master's degree require special help from highly qualified teachers. Unfortunately the University has so far failed in this respect. No doubt in Bombay and Poona there have been Inter-Collegiate lectures in Mathematics during the last few years due to the enthusiasm of some lecturers in the constituent colleges. But the system has not been very successful all the same. In the first place it is practically impossible to provide systematic lectures in even the most important branches of the subject; and secondly postgraduate teaching work is not recognised as of any importance in most colleges. The lecturers are expected to give the best of their time and energy to Honours and other undergraduate teaching. Whatever time can be spared after that is then given to the postgraduate work. It is not surprising therefore that highly qualified lecturers can do little justice to the work undertaken by them out of sheer enthusiasm for the subject. It is not the intention of this article to blame those teachers or to belittle whatever valuable work they have done in the past or are doing at present; all credit goes to them for undertaking such strenuous work quite voluntarily. But after all it cannot be denied that it is only their second best that they can give to this work, their best being required for the undergraduate classes in the college. If at all any blame is to be assigned for this it may be given to the general traditional attitude of colleges which places the undergraduate work on a much higher footing than the postgraduate and considers the latter to be of little consequence.

If proof were needed for the statements above it is afforded by the fact that many of our brilliant graduates in Mathematics either change their subject or prefer to go abroad for higher study in Mathematics immediately after their Bachelor's degree. This is also the reason why candidates from Bombay fare so badly in the Public Service Examinations, held in India. Graduates of the Bombay University with a couple of years' training abroad acquit themselves creditably in the Honours Examinations of English Universities and also get a fair share of the I.C.S. posts open to competition in England. This shows clearly that their foundations are truly laid and that in their training up to the degree stage and in their intellectual calibre they compare favourably with students from other Universities; but it is the lack of adequate facilities for postgraduate training that is to blame for their failure in India. (This applies no doubt to all subjects, but particularly so to Mathematics which requires much greater help than any other subject.)

To turn next to Research work in Mathematics it must be confessed that it *does not exist* in the University of Bombay. Papers have at times appeared in Mathematical journals from workers in the Bombay Presidency; but few of them are of any value or have been prepared solely under the auspices of the University. There are varied reasons for this state of things. In the first place it is once more the same old attitude in our colleges which puts a premium on undergraduate work. (In fact it is reported that in some colleges this attitude has been carried so far as to regard all research work done by lecturers as a disqualification, since it might lower the standard of the undergraduate teaching!) This puts an effective check on lecturers in Mathematics spending any time on original investigations.

Secondly there is hardly any incentive for research work in the University. Unless a person happens to be a genius like Ramanujan who could thrive in spite of the most disheartening circumstances, he is not in a position to do any original work. He lacks both the facilities and the atmosphere necessary for such work. The University Library for instance was at one time proverbial for its grossly inadequate stock of books on Mathematical subjects; and though it has progressed rapidly during the last few years it still requires considerable strengthening in this respect.

Further research work does not pay in our present attitude towards it. Here the writer may be taken to task for expecting workers to do original work for reward. He may be told that genius does not care for reward, and in fact strives all the more in poverty and want. That is no doubt quite true, but it must not be forgotten that geniuses are a law unto themselves and will come to the front in spite of all hindrances; what the University should aim at is the full development of the no less important class of intelligent and industrious young men who are the hopes of the University. Such persons do require help at a very critical period of their life to enable them to continue their work without starving and it is the business of this University to afford it. A Master of Arts or Science in Mathematics has already spent so many years at tremendous cost in equipping himself that he is not in a position to spend any more time doing original work. Even if he can afford it, he has few facilities for it. He considers himself fortunate if he is able to secure a teaching job in a college, but then he is so loaded with the junior undergraduate work that he has little time left for anything else. In fact in a few years he may even forget whatever Higher Mathematics he had learnt in his student days.

It is not easy to alter all this in a day; but the University can achieve a great deal by taking the initiative in this matter. If we look to the other Indian Universities like those of Madras, Calcutta, Allahabad, to name only a few, we see them forging ahead while the Bombay University is still in the same condition in which it was years back. It is therefore its imperative duty to set to alter these conditions without further delay.

The University must therefore open a Postgraduate Department of Mathematics as soon as possible. Its function will be (1) to provide adequate tuition for the Master's degree in Mathematics and (2) to serve as the centre for all original work in the subject. For this an adequate staff and a library furnished with journals and collected works of eminent Mathematicians will be necessary. The University Library can serve as a nucleus for the latter, but it will require considerable extension. It should also be open from early morning till late at night and should provide adequately furnished room for readers.

As regards the staff a beginning may be made by appointing two whole-time Readers assisted by a staff of Research Lecturers. The Readers should have the charge of the Department and should be necessarily Indians and preferably Bombay men. Their duty will be (1) to carry on research in Mathematics; (2) to initiate research and direct research students working under them; (3) to provide systematic courses of lectures in all the important branches of Mathematics (a) for students reading for the Master's degree and (b) for other workers interested in the highest developments in different branches of the subject, and (4) to conduct an efficient Mathematical Colloquium.

All these activities are of equal importance for the development of the Department. For providing courses of lectures these Readers will require considerable assistance. Some of it may be expected from lecturers in the local colleges provided their work in the Department is given sufficient importance by their respective colleges and they are correspondingly relieved from their undergraduate teaching work. But the main assistance should come from the Research lecturers attached to the Department and under the control of Readers. These Research Lecturers should be persons who have taken the Master's degree at least and who are making an intensive study of one or two branches of Mathematics under the auspices of the Department. They would turn out to be specialists of a high order in their particular lines and should be expected to help the Readers in the postgraduate lecturing or tutorial work. Their main duty however will be to carry on study and investigations in their own subjects and they should not therefore be loaded with too much lecturing or tutorial work, say not more than thrice a week on the average. They should also be expected occasionally to give short courses of lectures of a higher standard in their special branches of study for the benefit of other workers in the University.

The importance of the Colloquium cannot be exaggerated. At present the absence of one is sorely felt by all workers in mathematics, whether they be lecturers or students. But a Colloquium by itself without a postgraduate department, *i. e.* in the absence of a body of postgraduate teachers and investigators whose main business is research, would be merely a showy exhibit without any substance.

Now to turn to the question of recruiting the staff, Readers with adequate qualifications should not be difficult to find; but even if it is not possible to get the best possible men immediately, the creation of the department should not be postponed on that account. Candidates who may be expected to turn out suitable readers should be deputed if necessary to foreign Universities to equip themselves adequately. In fact for some time, provision may have to be made to send these Readers abroad for short periods at intervals of *four* or *five* years to keep them up to date in their subject. There is nothing derogatory to our prestige in such an arrangement and it would only be from a sense of false pride if we failed to keep in touch with the work going on in the West.

As regards the Research lecturers, they should be considered as the most important part of the scheme. A beginning may be made with about *six* such lecturers, increasing their number gradually to about *twelve*. They should be appointed for periods of two years, the appointments being renewable at the end of the period. They should be paid adequately say from Rs. 100 to 150 p. m. They may be expected to be absorbed in the staffs of the existing colleges sooner or later, and would thus spread the benefits of the Department throughout the Presidency.

The bulk of research students will be from those working for a Doctor's degree and the ordinary students will be those going up for the Master's degree. A sufficient number of adequate scholarships say of Rs. 75 p. m. for the research students and Rs. 50 p. m. for the ordinary students will be necessary for the success of the scheme, as otherwise many deserving students may be debarred from taking advantage of the Department.

It is unnecessary to elaborate the details any further at this stage. But it may not be out of place to meet some possible objections which may be anticipated. It may be asked for instance why Mathematics should receive undue preference in the University. It is certainly not the object of this article to run down other subjects. It would delight the writer if every subject of study had a postgraduate department in the University. But as pointed out above the needs of Mathematics are peculiar. In other subjects, particularly nonscientific, it is possible to advance knowledge by individual effort without elaborate preparations. Mathematics has passed beyond that stage and at the present time an investigator who has not been sufficiently trained up to the Master's degree would be handicapped considerably and would be able to do little valuable work. It has already been explained how the present haphazard system of Inter-Collegiate lectures is a poor substitute for such training; and until the University seriously takes up the work in hand as suggested it will continue to remain so. It must be remembered also that Mathematics is the key subject for the adequate development of most sciences (and some Arts subjects too) and with the prospective development of Science and Technology in the University, it becomes imperative to provide for a postgraduate department of Mathematics without delay.

Another possible objection may be raised by the mofussil colleges, as the scheme for some time at least will have to be confined to Bombay. However a beginning has to be made somewhere and Bombay being the Headquarters of the University where its Library is situated, it is the most suitable place for it. The benefits of the scheme will however spread throughout the Presidency and there is no reason why it should not be extended to other centres at a later stage.

In conclusion, an apology may be made to the readers for not going into the question of Funds. This question crops up everywhere and must be faced by those best fitted to deal with it. And remembering the objects with which the University was reconstituted in 1928, it must be solved satisfactorily without any delay.

THE CRISIS IN WORLD AFFAIRS

By

V. V. NARLIKAR, B. A. (Cantab)

Rayleigh Prizeman and Sir Isaac Newton Student

The crisis I am going to talk about is not a financial one but what is more important to the well-fed highbrow, a philosophical crisis. It is only fair to give this warning in the beginning; and if still you do not have a kind of feeling that you are let down, I am going to spring another surprise on you.

The world of our discussion is not our tiny world of five continents but that of nebulæ, globular clusters, stars and other celestial bodies in which the earth might be treated with the contempt which a particle of dust receives. Incidentally, the crisis is more universal than any other crisis we know of.

But the man of the street does not take a scientific crisis seriously much less a philosophical crisis. This attitude is, however, very regrettable especially in view of the recent scientific developments. If Prof. E. A. Milne is right the Sun may turn into a nova, any moment, which means that the sun might suddenly begin to burn very low. This would completely destroy the human race. A more critical situation, it is difficult to imagine.

Let us examine why a crisis in the scientific world does not appeal to the man of the street. I do not refer here to a crisis in the wireless business or some other crisis of a very practical nature but to a revolution in our intellectual outlook of the world of matter. It seems that a mathematician alone can be alive to a revolution of this type.

Mathematics is the most developed language of the head, and for this reason, most convenient to work with in the exploration of Nature. It is not therefore unreasonable to suppose that the deeper secrets of Nature should be unfolded first to the mathematician. The actual position is that, these secrets are actually disclosed to the mathematician first but in such an abstract form that they cannot be made intelligible to the man of the street. The latter does not usually understand these results and has, therefore, little faith in the Mathematician and a grouse against him. It seems to me improbable that the more advanced mathematical results could ever be made simple enough for the layman to understand. The world that the layman perceives is the world of his senses. The events of this world are not always strictly logical and the world as a whole is full of inconsistencies. To take a simple case, consider two boys standing on a straight horizontal railroad, facing each other, and at a distance of about four hundred yards. Each boy may then have the impression that the rails meet in the neighbourhood of the other boy. The sense-data have therefore to be modified by the mathematician so that the departure from the result of perception does not become unreasonable. Unless some modification is effected it would not be possible to use reason and imagination for further exploration. Euclid had therefore to introduce the axiom that parallels meet at infinity, which is certainly against the evidence furnished by the senses. To build a mathematical world, a scaffolding of axioms is first to be erected and the man of the street is to be trained to think that the scaffolding is sound. As soon as the building seems to have progressed long enough the scaffolding is removed; the layman loses sight of axioms and only the most striking results of advanced mathematics appear to matter. The mathematician looks only at the distorted image of the layman's world into his mirror of mathematical axioms. Yes! the vision is distorted because the axioms are only distorted experiences. The more complex experiences are the more complicated distortions of the mathematical world. It is possible to apply logic for the analysis of these distortions but their counterparts only defy logic. Thus the World of distortions seems to be the only world that can systematically be explored; to understand it is naturally beyond the man of the street.

The problem of the world has arrested the attention of some of the most imaginative heads in the field of mathematics, philosophy and religion, from very early times. Even the brilliant Descartes tried his hand at this game. He wrote a theory that the world arose out of a vaccum and sent it on for criticism to a friend at Paris who was reputed to be a well-read man. The friend replied that vaccum was not the current fashion in Paris. Next week Descartes wrote another theory according to which the world arose out of a plenum.

The modern theories of the world arose with the advent of the theory of relativity. It was Einstein himself who first introduced the concept of a finite and unbounded world. The most familiar surface which is both finite and unbounded is the surface of a sphere. Any point on the surface of a sphere can be fixed by means of two co-ordinates just as any position on the face of the earth is determined when the latitude and longitude are given. But our space is three-dimensional, it is to be considered finite and unbounded, it is like the surface of a sphere because we want to make as simple an assumption as possible; our space is therefore to be the surface of a four-dimensional sphere.

This fourth dimension is probably a difficult conception but it need not frighten anybody for that reason. We have been trained to take only three dimensions seriously. The new idea would, however, be soon assimilated into our habits of thought. H. G. Wells had it when he wrote the Time Machine which was long before the theory of relativity evolved. The way he looks at it is simple and striking and perhaps worth considering here ; he discusses what is commonly understood by the existence of a book. When we say that there is a book on the table we are certainly aware that the book has length, breadth and height ; in other words, that the book exists in three dimensions. But the existence in three dimensions is certainly not enough if one is to be aware of its existence. It must exist in time ; it must exist during the interval which passes from the beginning to the end of the remark, "There is a book on the table". From these and cognate considerations it can be seen that the fourth dimension as well as the familiar three dimensions is necessary for the description of the events of the world.

Space and time fuse into one unbreakable fourfold in the theory of relativity ; an observer may break it for his convenience because space and time play such essentially different parts in the ordering of our experiences. Even in the theory of relativity, it should be clearly understood, space and time are not really on the same footing ; only the two interact.

The spherical world which Einstein discovered is known by his name. The Einstein world is obtained from the modified gravitational equations of relativity. The modification consists in the introduction of the cosmological constant λ which was originally supposed to be zero. It is very interesting to notice that in his Oxford lectures last year Einstein has returned to his original conclusion that $\lambda = 0$; this step is highly controversial and Eddington and others take issue with Einstein on this point.

λ has been generally considered to be a positive constant although a few references can be given showing that λ may also be considered to be negative. The radius of the Einstein Universe turns out to be $1/\sqrt{\lambda}$. The distribution of matter in this model of the Universe is homogeneous and the connection between the total mass of the Universe, M, and the radius R, can be expressed in the simple form which runs as follows :— $\frac{2M}{R} = 3{\cdot}14159 \ldots$ This theory of the universe was rejected long ago because of the serious difficulties that came in its way.

Soon after this de Sitter obtained another solution of the modified gravitational equations of relativity. The de Sitter world is also spherical and its radius is $\sqrt{3/\lambda}$. It must be remarked that this radius as also what is called the radius of the Einstein Universe is the radius of four dimensional sphere whose surface is the usual three dimensional space. The de Sitter model of the universe is all empty. But it has a field of repulsion so that if a particle is introduced into this universe it is at once set into motion. The position in 1930, therefore, was as de Sitter himself has remarked, that there was one model of the universe in which there was matter but no motion while there was another in which there was motion but no matter. A new series of solutions was therefore needed in which the advantages of both these models would be found to be combined.

Such a solution was discovered in 1922 by Friedmann but it was soon buried and forgotten and had to be rediscovered by Lemaitre in 1927. Even Lemaitre's work was forgotten in 1930. By this time the excellent work which Hubble and Humasun had been carrying on at Mt. Wilson about the velocities of recession of the spiral nebulæ began to occupy the attention of the astronomers seriously. It was found out that the empirical law which Dr. Hubble had reached in his investigations was predicted by Lemaitre in his theoretical discussion of 1927. This is how the Lemaitre theory of the expanding Universe has come into the field.

The most interesting property of the solution that Friedmann obtained is that the radius R of the universe is a function of time. It is possible, on this account, to obtain expanding or contracting or even oscillating, universes. But at the moment only the expanding universe seems to be of special interest for the recession of the spiral nebulæ furnishes ample evidence that the universe is expanding.

It may not be fair to pass over this point without mentioning that vital theories have been put forward which go fundamentally against this theory of the expanding universe. The recession of the spiral nebulæ is inferred, in virtue of the Doppler principle from the reddening of the light that comes from the nebulæ. It has been suggested that this reddening may be due to other reasons; possibly the photon loses its energy either through leakage or through encounters with the interstellar particles. An examination of the question indicates that these possibilities do not account for the observed red-shift.

Once the expansion of the universe is established it is natural to try to account for its cause. Eddington has shown that the Einstein universe is unstable and has suggested that the genesis of the stellar system gave rise to a contraction or expansion in the Einstein universe. This problem has not yet been fully worked out. It must be remarked that in view of the different time scales even the very suggestion is contested that the expansion of the universe started with the evolution of this stellar system. Einstein seems to have completely ignored this question of the origin of expansion. He has only suggested that λ should be put equal to zero as it is possible to have an expanding universe even without λ.

The question has often been asked what this universe is expanding into? It has baffled those who have not an insight into this question. It would not be possible to answer the question here; perhaps the wiser course is to dodge the question in some way. Instead of taking the view that the universe is expanding let us consider that the universe is stationary but that we are all becoming smaller and smaller. The position in that case is really very serious. We are all reducing very fast, we will be reducing faster. Our position is certainly desperate because of our helplessness in the crisis. Perhaps the only remedy left is to ask the Mathematician to write a better theory.

TENDENCY OF MODERN MATHEMATICS WITH SPECIAL REFERENCE TO ANALYSIS*

By

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"I am sure" says J. W. L. Glaisher, "that no subject loses more than mathematics by any attempt to dissociate it from its history." For a correct perspective on the subject one is learning or teaching, the history of its development is absolutely indispensable. Again one among a multitude of reasons why study of the history of mathematics should be encouraged is that the history of mathematics is the history of human civilization. Human progress goes hand in hand with scientific progress; and all science as it tends towards perfection becomes mathematical in its basic ideas. Mathematics is philosophy. All mathematicians of note from Pythagoras (580–500 B. C.) and Plato (429–348 B. C.) of the past to Eddington and Einstein of the present are philosophers. History of mathematics is the most reliable index of the intellectual progress made and the best barometer to forecast the lines of immediate advance. A study of the history of mathematics enables us to form a notion of the present day tendency of the ever-progressing science of mathematics.

We say "ever-progressing" advisedly; for mathematics is not a dead science. It is pre-eminently an advancing science. The curve of its progress may not be capable of being always represented by a strictly increasing function of time. It possesses turning points; but the steps forward are always longer than the steps backward; and hence oscillation in any interval of time is ever positive and never zero. If the seventeenth and eighteenth centuries witnessed the Renaissance of mathematics "never more zealously and successfully has mathematics been cultivated than during the nineteenth and the present centuries". The last and present centuries have produced mathematicians of no mean magnitude, too many to mention. In 1903 Felix Müller declared that up to 1700 there were only 17 mathematical periodicals, in the eighteenth century the number rose to 210, in the nineteenth century it reached 950. Undoubtedly in the present century the number consists of four digits. One characteristic feature of the progress of mathematics may be mentioned here. If in the seventeeth and eighteenth centuries France and Switzerland led the van, in the nineteenth and twentieth centuries armies of mathematicians from all nations have wheeled into the front rank. Another feature, deserving mention, is that research in mathematics now-a-days is not confined to a subject or two; it embraces, like the notion of limit, all branches of mathematics, nay it creates new branches, *e. g.* Absolute Differential Calculus.

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* This is a chapter in the present writer's forthcoming book. For the substance of this essay he is indebted to *The Theory of Functions of a Real Variable* in two volumes by E. W. Hobson and *A History of Mathematics* by F. Cajori.

Third noteworthy characteristic of modern mathematics is its tendency towards generalization. Any limitation or restrictive assumption, conscious or otherwise, upon the generality of theorems, or of proofs, or of interpretation is repugnant to mathematical instinct. Generality is the life breath of modern mathematics. We propose to illustrate this feature of modern mathematics at some considerable length by choosing our examples from geometry and analysis.

One of the most fruitful sources of generalizing a theorem in geometry is afforded by the Principle of Continuity, which sharply distinguishes present day from ancient geometry. J. V. Poncelet (1788-1867) formulated this principle which states that "properties of figure which hold when the figure varies according to definite laws will hold also when the figure assumes some limiting position." We know that a parabola may be considered as the limiting case of an ellipse. Since an ellipse has two real foci and a centre, the principle of continuity goads us to guess that a parabola should possess two real foci and a centre too. *Now* it is well-known that a parabola does possess two real foci—one lying at a finite distance, the other at infinity with which its centre coincides. This is, however, one of the aspects of the principle of continuity. The study of the line at infinity and the circular points at infinity, due to Poncelet in relation to conic sections reveals the wide range of the application of this principle.

Extending our notion of number so as to include complex ones we have the following generalized theorem in algebra: Every rational integral algebraic equation of *n*th degree has *n* and only *n* roots. Borrowing the concept of these numbers from analysis we arrive at the following generalization of a theorem in pure geometry: Every finite straight line in the plane of a circle meets it in two points. If the two points have co-ordinates of the type $(\alpha \pm i\beta, \gamma \pm i\delta)$, where at least one of the two quantities β, δ is different from zero, the intersection of the line and the circle is incapable of any graphical representation. But our inability to visualize the truth of a theorem by a figure can, in no way, invalidate the truth embodied in the theorem. Can any one deny the truth that the number π exists? Then has any one ever constructed the segment of a straight line representing the number π? Figure is meant for those who have the imagination of a fly. With us it is a luxury, not a necessity. Hence it is possible for us to imagine the line at infinity and the circular points at infinity provided we first establish their existence by any *non-intuitional* method; non-intuitional since intuition, like Judas, often betrays us in mathematics.

Let us consider the analytic formulæ of homographic transformation, which is another an essentially modern concept.

$$\xi = \frac{x}{x-3}, \qquad \eta = \frac{y}{x-3}.$$

It is obvious that for every pair of values of x, y except those pairs for which x equals three there corresponds a uniquely determined pair of values for ξ, η. In the language of geometry the same fact may be expressed by saying that for every point (x, y) in $x-y$ plane there corresponds one and only point (ξ, η) in $\xi-\eta$ plane exception being made in case of those points which lie on the line $x=3$. Again it is easily proved that to every line in $x-y$ plane, except the line $x=3$, there corresponds a unique line in $\xi-\eta$ plane. This correspondence between the two systems is, however, destroyed by the fact that there exists no point or line in $\xi-\eta$ plane which corresponds to a point on the line $x=3$ or the line $x=3$ in $x-y$ plane. Our continuous progress along a continuous curve in $x-y$ plane, intersected by the line $x=3$, is marred by a discontinuity in $\xi-\eta$ plane by every point on $x=3$. To eradicate this discontinuity in $\xi-\eta$ plane and with a view to establishing a complete correspondence between the two systems we invent an 'ideal point' or 'a point at infinity' in $\xi-\eta$ plane which will correspond to a point in $x-y$ plane whose abscissa is three. Hence corresponding to the aggregate of all points in $x-y$ plane whose abscissæ are three we get an aggregate of ideal points or points at infinity in $\xi-\eta$ plane. Further since all points in $x-y$ plane having a common abscissa three form the line $x=3$, we naturally assume that all those ideal points or points at infinity in $\xi-\eta$ plane, which correspond to points on the line $x=3$, lie on a line which we propose to call the 'ideal line' or the 'line at infinity' in $\xi-\eta$ plane. This line is, however, necessarily a fictitious line. It is a straight line in the sense that it is made to correspond homographically to a straight line. It is a line at infinity in the sense that no finite point, real or imaginary, lies on it, since it is essentially composed of ideal points or points at infinity. Whenever we say that it is a line at infinity we intend to describe not its geographical position in the $\xi-\eta$ plane but only its nature. The only object that leads us to invent points at infinity and line at infinity is to secure continuity and generality of statement in dealing with certain analytical processes.

Solving the equation for homographic transformation for x and y we get

$$x=\frac{3\xi}{\xi-1}, \qquad y=\frac{3\eta}{\xi-1}.$$

Hence corresponding to points on the line $\xi=1$ in $\xi-\eta$ plane we get an aggregate of points in $x-y$ plane which we should now call ideal points or points at infinity in $x-y$ plane; and corresponding to the line $\xi=1$ in $\xi-\eta$ plane we have a line in $x-y$ plane which we have agreed to call the ideal line or the line at infinity in $x-y$ plane.

To sum up: by adding points at infinity and the line at infinity to each of the two systems we have established completely, without any exception, $(1-1)$ correspondence between the two systems. Hence the following generalization: To *every* point and line in $x-y$ plane there corresponds a unique point and a unique line respectively in $\xi-\eta$ plane and *vice versa*.

We have already stated the theorem: Every finite straight line in the plane of a circle meets it in two points. Having introduced the notion of the line at infinity in a plane we may further generalize this theorem as *every* line—not necessarily finite—lying in the plane of a circle meets it in two points. Now it can be proved that every circle in a plane cuts the line at infinity in that plane in always the same two points. These points we define as the circular points at infinity in the plane.

The importance and significance of introducing the notion of the Absolute *i. e.* the line at infinity and the circular points at infinity in a plane can scarcely be exaggerated. The Greeks studied the curves, what we now call the conic section, ellipse, parabola and hyperbola as isolated curves without ever dreaming that they form "a continuous chain, the ellipse passing into the parabola and the parabola passing into the hyporbola". Now they can be classified according to the nature of their intersection with the line at infinity. We now call a conic an ellipse, a parabola or a hyperbola according as it meets the line at infinity lying in its plane in two imaginary points, or in two real and coincident points, or in two real and distinct points. If the conic passes through the circular points at infinity, it is a circle. Lastly the theorem that the foci of a conic are the points of intersection of the tangents to the conic drawn from the circular points at infinity points out the use of these points in obtaining the foci of a conic. It is easy to go on multiplying examples of this nature indefinitely.

Next we proceed to illustrate the generalizing tendency of modern mathematics with an example or two, taken from analysis, "the common servant and chief ruler of the other branches of mathematics". Take the notion of function, one of the fundamental concept of analysis. In his 'Introductio in Analysin Infinitorum' published in 1748, L. Euler (1707–1783) defines a function of x to be a *single* analytical expression in x made up of powers, logarithms, trigonometrical ratios etc. of the argument. Sometimes he gives another definition of function: " The relation between y and x expressed in the $x-y$ plane by any curve drawn free-hand 'libero manus ductu' ". In his days the problem of determining the shape of a stretched string in a state of vibration occupied the best mathematical brains of the period. In 1747 J. d'Alembert (1717–1783), in 1748 L. Euler and in 1753 Daniel Bernoulli (1700–1782) produced solutions for the problem. These led to the conclusion that an arbitrary function, *i.e.* a function given graphically by a free-hand curve, though not itself a periodic one, is capable of being represented by a single trigonometrical series, which is necessarily a periodic series. Now the difficulty of the then mathematicians lay in their inability to reconcile this conclusion with their idea of a function. Their inability arose from their too narrow a notion of the nature of a function. "To them it was conceivable that a function given by a continuous curve might be so (*i. e.* by *a* trigonometrical series) representable, but since they regarded a function obtained by piecing two or more such curves together, not as one function, but as several different functions, it seemed to them impossible that such a broken curve could be represented by *one* trigonometrical series; a separate series seemed to be required for each separate portion of the given composite curve." Morever the idea that a function could admit of a representation by a certain analytical expression only in a *limited* range ran against the grain of opinion, obtaining in those days; and therefore, they contended that a function, given graphically by a non-periodic curve, could not be represented by means of a periodic series. In 1807 J. Fourier (1768–1830) proved conclusively that an arbitrary function, given graphically by a curve libero manus ductu, if not continuous, having finite discontinuities can be represented by a single trigonometrical series, called after him the Fourier series of the function. Further the idea was gradually assimilated that a *single* function may be represented by more than one analytical expression, the different analytical expressions corresponding to different intervals of the argument. Thus stood Euler's second definition of a function generalized in the first decade of the nineteenth century.

This generalization is, however, based on geometrical intuition and therefore is necessarily unarithmetical. Hence in accordance with a fundamental principle of analysis that it should be developed on foundations, purely arithmetical and independent of any geometrical or spatial intuition, P. G. L. Dirichlet (1805–1859) gave us the following more general definition of function: "y is said to be a single valued function of the variable x in the continuous interval (a, b) when a definite value of y corresponds to each value of x such that $a \leqslant x \leqslant b$, no matter in what form this correspondence is specified."

This definition of function, due to Dirichlet, differs from that of Euler's generalized definition of function in two respects. Firstly it is purely arithmetical. Secondly no limitation is placed, no restrictive assumption is made *a priori* regarding the mode of representing the functional relation between x and y. The correspondence between the values of x and y need not necessarily be capable of being expressed by means of an analytical formula such as $y=f(x)$, $\Phi(x, y)=0$. If, however, it admits of an arithmetical formula, there may be different arithmetical formulæ for different parts of the domain of argument x. Should these formulæ be mutually independent, they must form a finite set. If not, they may form an enumerable aggregate.*

The definition of function, given by Dirichlet, has, however, a drawback or two. According to this definition of function y is to possess one and only one value for each x in (a, b). This is but a trivial defect, the more serious one being that the definition excludes from the category of functions those given by analytical expressions, which for particular values of the argument in its range cease to define a single number. For instance sin x/x is not defined at $x=0$ in $(-1,1)$ Hence we have the following generalization of Dirichlet's definition of function: y is said to be a function of the variable x in its domain D if corresponding to each value of x in D we can obtain or are given one or more values for y. Setting $y=f(x)=\sin x/x$ for $0<|x|\leqslant 1$, and $f(0)=1$, y is a function of x in the domain $(-1, 1)$.

While every effort was made to emancipate the notion of function from geometrical intuition and from *a priori* representation by means of analytical formulæ no attention whatever was accorded to the domain of the independent variable over which the function is to be defined. In 1872 G. Cantor (1845–1918) gave the world the fruit of his researches in the theory of sets of points. The term function was once more destined to be redefined and regeneralized. Now a function of x need not be defined for *each* value of x in a *continuous* interval (a, b), as was required by Dirichlet's definition of function, but only for a particular set of points chosen from the continuum. Thus y is said to be a function of x if for each value of x belonging to a non-dense perfect aggregate, there corresponds or is given one or more values for y.

In analysis the domain of the independent variable is generally taken to be a continuous interval, finite or otherwise. The main object of the theory of functions is to classify functions according as they possess some peculiarity such as continuity, differentiability, integrability

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*For an example see Hobson's *The Theory of Functions of a Real Variable*, Vol. I, p. 261.

either throughout the domain of the independent variable or only at or in the neighbourhood of some values, specified beforehand, lying in the domain. Now it is possible to define these properties for a function the domain of whose argument forms not necessarily a continuous interval but only a non-dense perfect aggregate. Hence the goal, which the theory of functions sets out to achieve, may be attained by taking the last definition, and the most general definition given up till now, of function.

We have ample time at our disposal; but we are afraid the editor will grudge us ample space. Hence we must remain satisfied by pointing out that the theory of integration as developed from G. W. Leibniz (1646–1716) to H. Lebesgue and the theory of convergence of series of variable terms together with the notions of uniform convergence, sub-uniform convergence, infra-uniform convergence in an interval beautifully illustrate the tendency of modern mathematics towards generalization.

But excess of generalization of mathematics led to arithmetization of mathematics. As we have already said, the seventeenth and eighteenth centuries witnessed the Renaissance of mathematics. The Greek mathematicians eschewed, like a leper, the notion of infinitely small and infinitely great quantities. In his study of finding volumes of solids of revolution J. Kepler (1571-1630), who superseded Ptolemy by his epochmaking researches in planetary motion, utilized this notion with admirable success. But in the hands of I. Newton (1642-1727) and G. W. Leibniz (1646-1716) it was destined to revolutionize the whole science of mathematics. The new flame enticed a swarm of mathematicians only to burn their fingers. The contemporaries and successors of those two philosophers devoted themselves, heart and soul, to develop and apply infinitesimal calculus without ever giving a thought or two to its foundations. The child-like play with infinite series was bound to lead them to the land of paradoxes, a few of which will be given below. They handled infinite series with the same dexterity and skill practised by a tyro in tonsorial operation. In 1826 N. H. Abel (1802-1829) wrote Hansteen giving vent to his grievances against this *army* of mathematicians, every one of them aspiring to be *general*. "Everywhere one observes," said Abel, "the unfortunate habit of generalizing, without demonstration, from special cases; it is indeed marvellous that such methods lead so rarely to so-called paradoxes . . . . . . I believe you could show me but few theorems in infinite series to whose demonstration I could not urge well-founded objections. The binomial theorem itself has never been rigorously demonstrated . . . . . Taylor's expansion, the foundation of the whole calculus, has not fared better. . . . I mean to devote all my strength to spread light in the immense obscurity which prevails to-day in analysis. It is so devoid of all plan and system that one may well be astonished that so many occupy themselves with it,—what is worse, it is absolutely devoid of rigor." (J. Pierpont's *The Theory of Functions of Real Variables*, Vol. I.).

Comparing the growth of analysis in the time of L. Euler (1707-1783), J. L. Lagrange (1736-1813), P. S. Laplace (1749-1827) with that in the time of N. H. Abel, (1802-1829) A. L. Cauchy (1789-1857), K. F. Gauss (1777-1855), Cajori remarks: "During the former period we witness mainly a development with reference to form. Placing almost implicit confidence in results of calculation, mathematicians did not always pause to discover rigorous proofs, and were thus led to general propositions, some of which have since been found to be true in only special cases ..... But in recent times there has been added to the dexterity in the formal treatment of problems, a much-needed rigor of demonstration."

We may say that the latter trio of mathematicians added perspiration to their inspiration. With them the slogan was: Return to the rigour of the ancient Greek geometers.

We doubt if any one can find a better example than that of infinite series to illustrate the salient feature of the new era ushered in by N. H. Abel and A. L. Cauchy. I. Newton and G. W. Leibniz did recognize the necessity of setting up an inquiry re: the convergence of an infinite series; but they lacked in the *modus operandi*. Neither Leibniz nor Johann Bernoulli had the least insight in the fallacy

$$\tfrac{1}{2}=1-1+1-1+1-1+\ldots.$$

G. Grandi (1671-1742) went a step further and concluded that

$$\tfrac{1}{2}=0+0+0+\ldots.$$

By his researches on hypergeometric series Euler infused new life into the study of infinite series. Sometimes he sounded a note of warning against the use of divergent series; but very often did not believe in: act up to what one preaches. He never hesitated to write

$$0=1-3+5-7+9-11+\ldots..$$

According to him, since

$$n+n^2+n^3+\ldots.=\frac{n}{1-n},\quad 1+\frac{1}{n}+\frac{1}{n^2}+\ldots.=\frac{n}{n-1}$$

$$\ldots.+\frac{1}{n^r}+\ldots+\frac{1}{n}+1+n+n^2+\ldots.=0.$$

Cauchy and Abel led the analysts in building up the theory of infinite series on solid and rigorous foundations. In 1821 Cauchy published his 'Cours d'Analyse de l'École Royale Polytechnique'. It has been said of this book that "had it been studied more diligently by writers of text-books many a lax and loose method of analysis long prevalent in elementary text-books would have been discarded half a century earlier". Cauchy was the first mathematician to give a rigorous demonstration of Taylor's theorem. His tests re: behaviour of series are too well known to require mention here.

Abel, true to his word given to Hansteen made herculean efforts, in the short span of life allotted to him, to shed light on obscurities he encountered in every branch of analysis. The proof of binomial theorem given by Euler was anything but rigorous. Abel's demonstration leaves nothing to be desired from the view-point of rigour. It was in the course of the proof of this theorem that Abel established the following theorem on multiplication of two series: If two series are convergent, the product series, if it converges at all, must converge to the product of the sums of the two series. Before him Cauchy proved the theorem: If two series are absolutely convergent, their product is also absolutely convergent and converges to the product of the sums of the two series. This theorem was generalised by F. Mertens as: If only one of the two series is absolutely convergent, the product is convergent and converges to the product of the sums of the two series. Researches of A. Pringsheim lead us to the following conclusion: " The product of two conditionally convergent series can never converge absolutely, but a conditionally convergent series or even a divergent series, multiplied by an absolutely convergent series may yield a product series which converges absolutely."

The call of Abel and Cauchy back to the Greek geometers for rigour, caused not an inconsiderable flutter in the dovecotes of mathematicians of the period. A story goes that P. S. Laplace, who stressed the *formal* side of analysis in the company of L. Euler and J. Lagrange, attended the meeting in which Cauchy presented his researches on infinite series and immediately hastened he home to hide himself in his study until every series occurring in his ' Méchanique Céleste ' was examined for convergence. Most providentially for him every one was found to be so ! !

It is of course needless to add that all mathematicians were not converted, as Laplace was, to the view of infusing rigour into mathematical demonstration; for prejudices die hard, whether in the East or in the West. There exists a class of mathematicians who look askance at this struggle for rigour in mathematics. As late as the year 1904 Horace Lamb, in his address before the British Association in Cambridge said, " a traveller who refuses to pass over a bridge until he has personally tested the soundness of every part of it is not likely to go very far; something must be risked, even in mathematics. It is notorious that even in this realm of 'exact' thought, discovery has often been in advance of strict logic, as in the theory of imaginaries, for example, and in the whole province of analysis of which

Fourier's theorem is a type." We should be the last person not to concur, to the fullest possible extent, with the great mathematician; but we would like to add that all cannot afford to be travellers over the bridge. Engineers must exist to see their safe progress over the bridge that leads them to new lands: otherwise they will die the death of the citizens of Saint Louis Ray. Or varying the figure of speech we may say: Surpass Alexander the Great in the quest of conquests of new lands in the realm of mathematics; but eclipse Frederick the Great in the art of consolidation of the conquered lands.

Another repercussion of the Abel-Cauchy motto, return to the rigour of the ancient Greek geometers, was arithmetization of mathematics. Arithmetization of mathematics, stated briefly, means that mathematics should be developed on foundations based on pure arithmetic (*i.e.* science of numbers) and wholly independent of any notion of measurement of magnitude or geometrical intuition. In other words space-concept is to be displaced in favour of number-concept which alone should serve as the sole foundation of mathematics. Confining ourselves to analysis we proceed to show how it was built and developed in the seventeenth and eighteenth centuries on foundations foreign to pure arithmetic; and the process of arithmetization of analysis only began in the last century and as yet the end of the process is not in view.

If in accordance with the spirit of the age in which we are living we examine the foundations of analysis we come to the conclusion that few irreducible fundamental conceptions of analysis are those of number, variable, function, limit, and continuity. We have already pointed out at great length how mathematicians have struggled, with complete success, for more than hundred years to divorce the notion of function from geometrical intuition and place it on a basis, purely arithmetical.

Next take the concept of limit, which, like ether, permeates everywhere in analysis. The method of limits had a geometrical origin in the Method of Exhaustion invented by Greek geometers to find out lengths, areas, and volumes in simple cases. This method, coupled with the notion of infinitely small and infinitely great quantities was successfully used by Kepler in obtaining areas and volumes in certain simple cases. Thus a circle was conceived by him to be composed of an infinitely great number of triangles, one vertex of each triangle coinciding with the centre of the circle and two lying in the circumference so that the base is infinitely small. Similarly the length of an arc of a curve between two fixed points on it was the limit of the perimeter of a properly inscribed polygon when the number of its sides is made indefinitely great in such a way that each of its sides becomes infinitely small. In all cases not a grain of doubt was entertained as to the existence of the limit concerned. Why! it always exists as geometrical intuition warrants us. With old mathematicians the fact that a curve has a length, or a closed curve has an area, or a solid bounded on all sides possesses a volume was as "obvious" as their own existence; obvious in the sense that no proof was required to show their existence. With us too they are "obvious" in the sense that a little thinking will suggest us a formal proof to establish their existence. But a little thinking *is* to be gone through. That this conception of limit, based as it is on geometrical intuition, cannot but be defective and slipshod has been confirmed *a posteriori* and beyond doubt by modern researches. From geometrical intuition it was assumed that an arc of a continuous curve between two fixed points on it possesses a length. It is proved now that this is false; *e.g.* the curve given by $y=f(x)=x \sin \frac{1}{x}$ in $0<|x|\leqslant 1$ and $f(0)=0$, though continuous everywhere in $(-1,+1)$, is not rectifiable between the points $[-1, f(-1)]$, $[1, f(1)]$. Again a continuous function was assumed to possess a derivative at every point of its continuity; for being continuous it can be represented by a continuous curve, which as it is obvious from geometrical intuition, must possess a tangent at every point. In 1861, K. Weierstrass (1815-1897), one of the greatest exponents of the movement of arithmetization of analysis, made the following shocking discovery. The continuous curve given by $y=\sum_{0}^{\infty} b^n \cos \pi (a^n x)$ where a is an odd integer >1 and $0<b<1$; $ab>1+\frac{3\pi}{2}$ possesses no tangent at any point, *i. e.* a function though continuous everywhere has derivative for no value of its argument. Cauchy was the first mathematician to recognize the fact that existence of limit must be proved independently without recourse to geometrical intuition and that notion of limit as based on it must be discarded for the one built on purely arithmetical foundations.

Now before we can turn to the arithmetical definition of limit we have to say few words re: the notion of numbers. Until 1870 a number was defined to be the ratio of a segment of a straight line to a unit segment; and an irrational number was looked upon as the ratio of two incommensurable segments. Now this notion of number, metrical as it is, is based on the theory of magnitudes and conception of irrational number involves an appeal to our intuition of measurement of extensive magnitudes. Now the process of infusing rigour in mathematics and of arithmetization of analysis demands that metrical and intuitional concept of number must be superseded by a purely arithmetical definition of it. And in his endeavour to achieve this goal many a mathematician tumbled against the rock of irrational numbers. A great analyst, to wit, no less than Cauchy, failed in his attempt to define an irrational number. In his *Cours d'Analyse*, he says "an irrational number is the limit of diverse fractions which furnish more and more approximate values of it." Here Cauchy reasoned in vicious circle. He assumes the existence of rational numbers only (diverse *fractions*). We know that a sequence of rational numbers possesses a limit other than a rational number *e.g.* $\sqrt{2}$ is the limit of the sequence of rational numbers 1, 1·4, 1·41, 1·414, 1·4142, ... Now if the limit of the said diverse fractions is a rational number the definition fails to define an irrational number. Again, since Cauchy confined himself only to the domain of rational numbers, if the limit of the said diverse fractions is anything but a rational number it is non-existent and fictitious and hence the definition cannot define an irrational number. Thus Cauchy assumed the existence of what he professes to define arithmetically.

Now, therefore, it should be clear that arithmetical theory of limits "is essentially dependent upon the theory of irrational numbers; for in default of an arithmetical theory of irrational numbers all attempts to prove the existence of a limit of a convergent sequence are doomed to inevitable failure; and this for the simple reason that a convergent sequence of rational numbers does not necessarily possess a limit which is within the domain of such numbers." Hence to put the whole theory of irrational numbers on an arithmetical basis we have to develop it without any reference to limits; and after achieving this object we can construct a purely arithmetical theory of limits.

Starting with positive integral numbers, we enlarged arithmetically our conception of number so as to include positive fractions, and negative numbers; and thus created the class of rational numbers. Similarly starting with rational numbers it is possible to re-enlarge *arithmetically* our conception of number so as to embrace irrational numbers. This has been done by four mathematicians almost simultaneously but independently of each other. Year 1872 witnessed the science of mathematics receiving the arithmetical theory of irrational numbers from K. Weierstrass (1815–1897), from C. Méray (1835–1911), from R. Dedekind (1831–1916) and lastly from G. Cantor (1845–1918).

In the theories of Méray and Cantor an irrational number is defined by an infinite ascending aggregate of *rational* numbers $a_1, a_2, a_3,$ ....which have the property that corresponding to any arbitrarily given positive *rational* number ϵ we can find an integer $n_0(\epsilon)$ such that $|a_n - a_{n+m}| < \epsilon$ for every $n \geqslant n_0$ and for $m = 1, 2, 3 \ldots\ldots$

Dedekind defines an irrational number as follows. Let all *rational* numbers be divided into two classes L and U so that (i) every rational number belongs to one or other of the two classes, (ii) each class contains at least one number, and (iii) every number in class L is of lower rank (*i.e.* less) than that of every number in class U. Every such division, or as the term goes, section of rational numbers corresponds to a real number. Should either class L possess a number α of rank higher than that of any number belonging to L or class U contain a number α of rank lower than that of any number belonging to U, then the section of rational numbers is said to define a real number corresponding to the rational number α. In case neither L has a number of rank higher than that of any number belonging to L nor U possesses a number of rank lower than that of any number belonging to U, then the section of rational numbers is said to define a real number which corresponds to an irrational number. Thus Dedekind defined every 'cut' (French coupure; German schnitt) in *rational* numbers to be a real number, the 'closed cuts' giving us the system of rational numbers, and the 'open cuts' irrational numbers.

Now that we have placed the theory of irrational numbers on fundations, purely arithmetical, without any recourse to notion of limit, it is possible to develop the theory of limits on an arithmetical basis.

If $x_1, x_2, x_3 \ldots\ldots\ldots x_n \ldots\ldots\ldots$ is a sequence of *real* numbers such that there exists a number x possessing the property that corresponding to any arbitrarily chosen positive *real* number ϵ, we can find a value of n, say n_0 (ϵ) such that $|x-x_{n_0}|$, $|x-x_{n_0+1}|$, $|x-x_{n_0+2}|$ ......are all of rank lower than that of ϵ, then the number x is called the limit of the sequence $x_1, x_2, \ldots\ldots$ The definition, given above, presupposes the existence of the number x. The following theorem, called the General Principle of Convergence by P. Du Bois-Reymond (1831–1889) gives us the criterion for its existence.

The necessary and sufficient condition that a sequence of real numbers $x_1, x_2, \ldots\ldots x_n \ldots\ldots$ may have a limit, is that corresponding to any arbitrarily given positive real number ϵ a value of n, say n_0 (ϵ). can be found such that $|x_n - x_{n_0+1}|$, $|x_{n_0} - x_{n_0+2}|$, $|x_{n_0} - x_{n_0+3}|$,......... are all of rank lower than that of ϵ.

The present writer holds the view that the process of arithmetization of analysis should not only alter the foundations of analysis but should also be extended so as to alter the phraseology used in books on analysis. In any scheme which professes to put analysis on foundations purely arithmetical, the theory of measurement of magnitude is taboo. Hence it naturally and logically follows that in analysis we should put the terms 'less', 'equal', 'greater', borrowed from that theory, under a taboo, and instead employ the terms 'lower rank,' 'same rank' 'higher rank' which belong to pure arithmetic. Again for similar reasons the terms 'point', 'set of points' should be discarded in favour of 'value', 'aggregate of values'. Thus instead of saying that $| x_{no} - x_{no+1} |$ is less than ϵ we prefer to say that $| x_{no} - x_{no+1} |$ is of lower rank than that of ϵ. Similarly instead of writing that $f(x)$ is continuous at point $x = a$, it would be more logical to say that $f(x)$ is continuous at value $x = a$. Here the symbol '$=$' should be defined to mean 'of the same rank'. One may contend that Cantor–Dedekind axiom enables one to establish one—one correspondence between the arithmetical continuum and the linear continuum; and hence one is justified in taking *points* as the images of *numbers*, and the numbers as the signs of the points. Yes; granted most unhesitatingly. But we still stick to the position we have taken; for boycott on foreign 'goods' is ever so desirable and beneficial.

We cannot conclude this part of our essay without a reference to Kronecker's scheme of arithmetization of analysis. So far we applied that term to denote the process which places analysis on foundations independent of all notions borrowed from "the idea of measurable magnitude, the fractional, negative, and irrational numbers being so defined that they depend ultimately upon the conception of integral numbers" and which involve no appeal to our intuition of space, time and motion. Hence analysis built up on a purely arithmetical basis is a science which deals with numbers only—rational or irrational, integral or fractional, positive or negative. But there exists a school, headed by L. Kronecker (1823-1891), which advocates another scheme of arithmetization of analysis. Kronecker's contention is that it is not necessary to enlarge our primary conception of positive integral numbers so as to include negative, fractional and irrational numbers. The ideal which this school sets out to reach is that "every theorem in analysis shall be stated as a relation between integral numbers only, the terminology involved in the use of negative, fractional and irrational numbers being entirely removed". E. W. Hobson characterizes this ideal as a "species of Mathematical Nihilism".

To sum up, we may add that the Abel-Cauchy call back to the Greek geometers for rigour, set on foot the movement of arithmetization of analysis. Since its inception in 1825 the movement has never flagged even to this day. The ball set in motion from Norway and France rolled into Germany only to get accelerated by great mathematicians like K. Weierstrass, G. Cantor, R. Dedekind and L. Kronecker. If the goal of the school to which Kronecker belonged is attained, it will be the greatest triumph of human intellect in the realm of thought.

It is yet too early to grasp the full significance of this quest for rigour. It may take us to the Mecca of mathematics, visualized by the messiah Kronecker and his followers, or, at worst may lead us to successive approximations to absolute rigour. One aspect of this quest is however absolutely clear. Just as it compels us to re-examine the foundations of mathematics, it demands that the term mathematics should be redefined.

With Aristotle we define mathematics as "the science of quantity". In the age in which he flourished the only subjects of some magnitude were geometry and trigonometry, each of which involves magnitudes. Every problem was brought within the compass of ruler and a pair of compasses. But since his days many a new branch has been added to mathematics where direct measurement, if not out of consideration, is altogether impossible. Direct measurements, unless by accident, are seldom correct; and we are forced to take recourse to methods of indirect measurement. We measure the distance between two stars only indirectly; we calculate the mass of the sun or an atom, not by putting it into a pair of scales but, only indirectly. We find the velocity of a moving particle at a given instant, not by direct measurement but, only indirectly by obtaining the limit of a certain sequence. Hence A. Comte (1798-1857), a French philosopher and mathematician defined mathematics as "the science of indirect measurement". But as we have already said, mathematics is pre-eminently a progressive science and hence its definition must be a function of its argument, progress. There are several modern branches of mathematics *e. g.* projective geometry, analysis, the theory of groups, tensor calculus which are founded on a basis free from all notions of magnitude and measurement. The very interesting theorem : If two triangles are self-conjugate w.r.t. a conic, their six sides touch a conic and their six vertices lie on a conic, has as much relation to notions of quantity and measurement as the Riemann integral of $f(x)dx$ in (a, b) to notions of power series and uniform convergence. Again, as we have already seen, "the notion of continuum—the central supporting pillar of Modern Analysis—has been constructed by K. Weierstrass, R. Dedekind, G. Cantor and others, without any reference whatever to quantity so that the number and magnitude are not only independent, they are essentially disparate." Hence Comte's notion of mathematics stands in need of redefinition. Several new definitions of mathematics have been put forward, one by B. Peirce in 1870, another by A. Kempe in 1894, third by Bertrand Russell, of versatile genius, in 1901, and few more by other writers. Of these Russell's definition makes a profound appeal to us. Very tersely and succinctly it gives us an idea of the extreme generality and extreme subtlety of certain parts of modern mathematics. We have been taught that mathematics is an *exact* science. Bertrand Russell tells us that "mathematics is the subject in which we never know what we are talking about nor whether what we are saying is true".

THE SURPRISE IN MODERN PHYSICS

By

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> **" Determinism has faded out of theoretical physics. Its exit has been commented on in various ways. Some writers are incredulous and cannot be persuaded that determinism has really been eliminated. Some think that it is only a domestic change in physics, having no reactions on general philosophical thought. Some imagine that it is a justification for miracles. Some decide cynically to wait and see if determinism fades in again."—[EDDINGTON: *Presidential Address to the Mathematical Association, 1932*]**

The present century is characterised by a rapid succession of startling changes in our scientific thought. First relativity theory, then quantum theory, then the new quantum-mechanics—it looks as if with each succeeding decade we are to be presented with a new theory—and no one is sure when and whether the last word is to be said. It is all so very bewildering. The purpose of this article is to give an account of that aspect of the new theory—the Uncertainty Principle—which, in the opinion of scientists like Eddington, holds forth a hope of clearing up one of the deeper contradictions between human processes and physical processes, between the doctrine of free will and the law of causality. " Mind ", said Descartes, " is a thinking unextended substance : and matter is an unthinking extended substance." This contrast between matter and mind has perhaps been one of the outstanding difficulties in the way of Philosophers' quest for a common plan which controls the progress of events in the physical as well as the organic world. While thinkers in every age have been at pains to release the human mind from external control and establish the freedom of the will, scientists, on the other hand, have (so far at any rate) blessed the Creator for subjecting every physical process to some causal law. While addressing the members of a Scientific Association in 1927, the writer had an occasion to stress this very aspect of nature—the uniformity of her laws, the order in her doings, the determinism in her plan. If, it was pointed out, all religions, moral sciences and systems of philosophy are at bottom supported by the hypothesis of "Justice of the Universe", the physical sciences also start with the hypothesis of "Order of the Universe". Every occurrence however trivial, every process however minute, it was argued, is governed according to some relentless, inexorable law of nature,—some cause-and-effect relation. Given a definite set of conditions, a certain definite result, and none other, must follow. If say pure water be heated at ordinary atmospheric pressure, then it must begin to boil at 100^0 centigrade, whenever and wherever you perform the experiment. The whole of this physical universe was thus like a clock once wound up, but running down according to a fixed plan. This is nothing short of 'fatalism', in the world of science—and not only did we welcome it, we even sought to widen the limits of its domain. And with what end in view? Just to be able to account for every occurrence in nature, just to eliminate from our vocabulary expressions like the 'caprice of Nature'.

Quite unexpectedly, however, during the course of the last ten* years there has emerged in the developments of Physics what is being termed as the Uncertainty Principle; and it appears that Science will have to withdraw from its "determinist"—fatalistic—attitude which it has consistently adopted for two hundred years. No wonder this should cause a general flutter, in which different people have reacted differently to this new development. One may profitably pause for a moment at this stage and briefly recall the sequence of successive developments that preceded, and in a sense led to, the discovery of the new doctrine.

It is a common story that Newton's corpuscular theory of light which held the field for a whole century, broke down on the phenomenon of interference, and had to make room for Huygen's wave-theory. But later on the wave theory, in its turn, came to be confronted by what is known as the '*Photo-electric effect*'. When ultra-violet rays fall on a piece of metal in vacuum, a large number of electrons are shot off from the metal at a high velocity. Lenard pointed out that (1) the *intensity* of the exciting light which varies inversely as the square of the distance, has no influence on the *velocity* of the emitted electrons, but determines only their *number*; and that (2) the *frequency* determines only the *velocity* of the electrons, but has nothing to do with their *number*. These facts could not be explained on the basis of the classical wave-theory. It would appear that light-energy does not spread out quite uniformly in all directions becoming continually less intense, but always remains concentrated in certain definite bundles or *quanta*, depending only on the colour, and that these quanta move in all directions with the velocity of light. Such a light-quantum, striking the metal communicates its energy to an electron, and the energy always remains the same, however great may be the distance from the source of light. We have thus Newton's corpuscular theory resuscitated in another and modified form. The dilemma that faced the scientists was that neither the wave-theory of light, nor again the quantum theory of light could by itself explain *both* the phenomena of Interference and 'Photo-electric effect'.

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* See N. Bohr's Article. [*Nature*, vol. 121, p. 580 (1928)]

These two were not the only phenomena which presented a conflict. Evidence poured in from various directions which showed that not only light but both light and matter possess this remarkable duality of character in that they sometimes are found to behave as waves, and at other times as particles. The two concepts, particle and wave, are so distinct that it was impossible to conceive how one and the same entity can be a form of wave-motion, and be composed of particles at the same time. The obvious assumption that would suggest itself was to suppose that two separate entities—one having the properties of particles, the other of waves—are in some way combined to form 'light'. But this would not work, as such a theory is unable to bring about the intimate relations between the two entities which seem required by the experimental evidence. The difficulty was solved by Heisenberg[1] who put forth the view that the apparent duality arises from the limitations of our language.

To appreciate Heisenberg's way of removing the contradiction one cannot do better than to follow the discussion as far as possible in his own words. All that our experiments reveal is that light sometimes behaves as if it possesses some of the attributes of a particle, but there is nothing to show that it possesses all the properties of a particle; similar statements hold for matter and wave-motion. Heisenberg says that both the pictures—particle and wave—are incomplete and have only the validity of analogies which are accurate only in limiting cases. It was Eddington, probably, who first suggested the word "*Wavicle*", to describe the ultimate nature of "light"—which is both a wave and a particle. Our language was invented to describe the experiences of daily life which consist only of processes involving a large number of atoms. It is not therefore surprising that it should fail to describe the sub-atomic processes. Fortunately mathematics, which perhaps is the most perfect language, is not hampered by this difficulty, and the new quantum-mechanics has been able to invent a scheme which seems entirely adequate for our purpose. For visualization, however, we have to content ourselves with two incomplete analogies—the wave and the particle, and assume with Dirac[2] that the photons (*i. e.* particles of light) are controlled by waves, in some way which cannot be understood from the point of view of ordinary mechanics. This intimate connection between waves and particles is of very great generality in the new quantum mechanics. *All* particles

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1. *The Physical Principles of the Quantum Theory* (1930).
2. *The Principles of Quantum Mechanics*, (1930).

are connected in this way with waves, which control them and give rise to interference and diffraction phenomena under suitable conditions. The influence of the waves on the motion of the particles is less noticeable the more massive the particles, and only in the case of photons, the lightest of all particles, is it easily demonstrated.

Such or nearly such is the position taken up by the new quantum mechanics. Dirac suggests a simple experiment to demonstrate how light can yet exhibit wave-like properties, even when it is supposed to consist of photons. We shall mention it here because it also points out how and why a release from the law of causality is essential. Suppose that we have a beam of plane-polarized light passing through a polariscope and getting resolved into two components polarized at angles α and $\alpha + \frac{1}{2}\pi$ with the direction of polarization of the incident beam. And let the incident beam consist of only a single photon. Let us find the energy in each of the two components. According to the quantum theory, we would expect the whole of the energy in one component, or the whole of the energy in the other component, but never a part in the one and a part in the other. This is because no experiment can reveal a fraction of a photon. Now, if one did this experiment a large number of times (or if there be a large number of photons in the incident beam), one would find in a fraction $\cos^2\alpha$ of the total number of cases that the whole energy is in the α-component, and in a fraction $\sin^2\alpha$ that the whole of the energy in the $\left(\alpha + \frac{\pi}{2}\right)$-component. Now it is open to us to give the following description of what happens. The photon has a *probability* $\cos^2\alpha$ of appearing in the α-component and $\sin^2\alpha$, of appearing in the other component. This would lead to the correct distribution of energy as demanded by the classical wave-theory,—when the number of photons is large.

What the reader has to note in this way of explaining things is that the individuality of the photon is preserved in all cases, but only *at the expense of determinacy.* The result of an experiment is not determined, as it would be according to the classical theory, by the conditions under the control of the observer. You have to perform it a large number of times;—or a large number of atoms must be simultaneously dealt with; and what we get is the most probable result. This lack of determinacy in the result of an experiment in which an individual atom (or a photon) is involved is to be traced, as pointed out by Bohr, to the disturbance which the observation makes, although one cannot enquire closely into how it comes about. The apparent failure of causality is due to a "theoretically necessary clumsiness in the means of our observation".

Now what do we mean by "a theoretically necessary clumsiness in the means of our observation" ? It is only another way of putting that there is necessarily a lower limit to the accuracy of our experiments, a limit to the determinacy. It has been said that the state of affairs in the quantum theory is not unlike that of the early days of relativity theory; and the Uncertainty Principle plays much the same rôle in the new theory as did the examples of 'clocks' and 'measuring rods' in the relativity theory. But there is just this difference. The relativity theory fulfilled the traditional requirements of science in that it permitted the division of the world into the observer and the observed, and thus did maintain the law of causality. This however is the very point at which the difficulties of the new quantum mechanics begin. In atomic physics, the concepts of 'clocks' and 'rods' need no immediate consideration, as in most of the phenomena $\frac{1}{c}$ is negligible. But there enters the interaction between the observer and the object ! In the classical physical theories—which mainly explained macroscopic phenomena—we could assume that the interaction is negligible. Its effect, at any rate, could be eliminated by means of 'control' experiments. In atomic physics the interaction becomes uncontrollable because of the discontinuous changes characteristic of atomic processes. The immediate consequence of this circumstance is that in general every experiment performed to determine some numerical quantity renders the knowledge of others illusory, since the uncontrollable perturbation of the observed system alters the values of previously determined quantities. A number of examples have been given by Bohr, Darwin* and Heisenberg to illustrate this point. Perhaps the simplest of them is the following :—

Let it be propsed to determine the position of a free electron by the use of a microscope. Suppose that the electron is moving at such a distance from the microscope that the cone of rays scattered from it through the objective has an angular opening ϵ. If λ is the wavelength of the light illuminating the electron, then the uncertainty in the measurement of the x-co-ordinate according to the laws of optics governing the resolving power of any instrument is

$$\Delta x = \frac{\lambda}{\sin \epsilon}$$

But for any measurement to be possible, at least one photon must be scattered from the electron and pass through the microscope to the observer's eye. This photon gives to the electron a Compton-recoil of order of magnitude $\frac{h}{\lambda}$. The recoil cannot be exactly known, since the direction of the scattered photon is undetermined within the bundle of rays entering the microscope. Thus there is an uncertainty of the recoil in the x-direction of amount

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* 'Roy. Soc. Proc.' A, Vol. 130, p. 632 (1931).

$$\Delta p_x \sim \frac{h}{\lambda} \sin \varepsilon.$$

And thus it follows that for motion after experiment

$$\Delta p_x : \Delta x \sim h.$$

This is only one of the many illustrations that show how uncertainty is inevitable.

It was the relativity theory that made us first realize that the physical world differs from the ideal world as we conceive it in terms of our daily experience. We had to get our mind used to realize that the ordinary concepts could only be applied to processes in which the velocity of light could be regarded as practically infinite. Similarly, most of the paradoxes of the atomic physics now require a further renunciation of our old and cherished ideas. The most important of these is the idea that natural phenomena obey exact laws, in other words, the law of causality. Now to co-relate a definite cause with a definite effect has sense only when both can be observed without introducing a foreign element disturbing their inter-relation. And this is possible in the case of large-scale phenomena, but not in the case of phenomena in which we have to deal with an individual atom.

Several writers—(Darwin among them)—believe that the philosophical discussion regarding the question of human free will is not touched by the above Principle of Uncertainty. It is doubtful, they say, if any of the old deterministic descriptions of nature were antagonistic to the doctrine of human free will; for, it is a presumption to suppose that the organic world is controlled by the laws of physics and chemistry. "Since the Heisenberg Uncertainty relations are also laws of the inorganic world, it is again a presumption to suppose that they control those activities in which human beings feel that they have freedom of choice."

One may, nevertheless, be permitted to point out that the new principle serves at any rate to remind the 'die-hard' determinist that there is nothing in Physics which makes the idea of human free will absurd. "The new Physics", observes Eddington, "opens the door to indeterminacy of mental phenomena, whereas the old deterministic physics bolted and barred it completely." Looking at the whole position now from a layman's point of view, one cannot help being struck by the *now arising* exact parallelism between the social sciences and the physical sciences. In the former, when we speak of large masses of individuals, we do get some general statistical laws,—although these may not be applicable to individual cases, because of the freedom of the will. Quite similarly, in the physical world, when we have to deal with phenomena in bulk, that is in which a large number of atoms are involved, we can formulate some definite laws—but they lose their validity in atomic processes, in which we have to deal with single atoms.

THE "PYTHAGOREAN THEOREM" IN INDIA

By

V. B. NAIK

The property of right-angled triangles, *viz.*, "In all right-angled triangles, the square on the side subtending the right angle is equal to the squares on the sides containing the right angle", is no doubt remarkable from its importance and wide range of application in Geometry, as well as from the essential part it plays in other allied branches of Mathematics. But apart from this, it possesses considerable special interest from the historical point of view. It is one of those mathematical truths, the recognition of which especially in its abstract form and in regard to its applicability to purposes not only theoretical but also practical, implies a good deal of previous advance in certain formal types of mathematical thought. It is therefore not a little surprising to find from recent researches into past records, such as old religious texts, papyri and inscriptions, that some knowledge of the property in question can be traced even to the earliest of historical times, and that even in those remote days it had been already employed in the practical arts of measurement and building. This remark holds good, to a greater or less extent, of most of the ancient peoples whose civilization preceded that of the Greeks, such as the Egyptians, the Babylonians, the Chinese and the Indians. There is however little evidence to show that the knowledge of any of them, with the exception of the Indians, went much beyond the recognition and use of the fact that a triangle whose sides have lengths in the ratio 3 : 4 : 5 is a right-angled triangle. In the case of the Indians it is almost beyond doubt, as will be presently seen, that they not only knew of more cases of right-angled triangles with rational sides, even in the early past, but that they were also the earliest to discover and prove the theorem in all its generality and to use it for various geometrical constructions of a general nature. Further they had through its knowledge come to recognise the existence of irrational numbers, and appear to have devised a general method for using them in calculations.

Western scholars who generally look upon the whole subject of mathematics and especially geometry as the sole achievement of the Greek mind at least in its theoretical or scientific aspect attribute the discovery as well as the first demonstration of the general theorem of the square on the hypotenuse to Pythagoras,[1] the Greek philosopher, who is said to have lived from 569 to 500 B. C. They do this mainly on the testimony of Greek writers of the 1st and subsequent centuries A. D. who are fond of recounting tales attributing every thing of unique interest or importance to the "godlike men of old,"[2] such as Thales, Pythagoras and other Greek philosophers of antiquity. These writers make vague and often conflicting references to old traditions regarding Pythagoras, vying with each other in the invention of fables, relating to his travels, his miraculous powers and his teachings.[3] Thales and Pythagoras left behind no written records of any discoveries made by them. In fact the original works, if any, of all the forerunners of Euclid (300 B. C.), Archimedes (287–212 B. C.) and Apollonius (260–200 B. C.) have been lost. It is said that a history of Greek geometry and astronomy was written by Eudemus (335 B. C.). But this too has been irrecoverably lost. There exists, however, in the commentary of Proclus (410–485 A. D.) on Euclid, Book I, a historical summary which is believed to be based on Eudemus' history. This summary, often called the Eudemian summary, is the main basis[4] on which ancient Greek geometry is reconstructed, other material being such scattered notices as are found in the *Collection* of Pappus (300 or 400 A. D.) and the works of writers subsequent to the beginning of the Christian Era. So far as the theorem of the square on the hypotenuse is concerned, it has been shown by G. Junge (Novae Symbolae Joachimicae, Halle A. S., 1907 pp. 221–264,)[5] that "the Greek literature which we possess belonging to the first five centuries after Pythagoras contains no statement specifying this or any other particular great geometrical discovery as due to him".

While the Grecian claim to the original discovery of the theorem in question thus rests on vague tradition, documentary evidence has on the other hand come to light which clearly shows that the Indians had discovered and proved the theorem at least as early as, if not much earlier than, 800 B. C., and it may even be considered very probable that Pythagoras who is known to have travelled far into the East might have obtained the knowledge of it from the Indians. In his valuable edition of the *Thirteen Books of Euclid's Elements*, (Sir Thomas L.) Heath has written a special note[1] on the subject of the "Pythagorean Theorem" in India, during the course of his comments on Proposition 47 of Book I. He attempts to examine therein the respective claims of the Indians and the Greeks regarding the discovery as well as the proof of the theorem. While reading the comments and the note one cannot fail to notice a difference in treatment and attitude in judging of the two claims. The reasoning followed in dealing with the claim of Pythagoras is so far-fetched, so liberal in making favourable assumptions and so respectful to traditions that one begins to wonder at the spirit of cautious scrutiny, the exacting insistence on positive evidence and the rigid scepticism which are so profusely brought to bear on the Indian claim.

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[1] D. E. Smith, *History of Mathematics*, Vol I, p. 59; Sir Thomas L. Heath, *A Manual of Greek Mathematics*, p. 3, pp. 95–100 ; F. Cajori, *History of Mathematics*, pp. 15–18.

[2] Vide *e. g.* T. L. Heath, *Thirteen Books of Euclid's Elements*, Vol. I, p. 343.

[3] Smith, *History of Mathematics*, Vol. I, p. 71.

[4] Cajori, *History, of Mathematics*, p. 15 ; Heath, *Thirteen Books of Euclid's Elements*, Vol. I, p. 29.

[5] Referred to in Heath, *Thirteen Books of Euclid's Elements*, Vol. I, p.351.

An investigation into the Greek and the Indian claims involves the following points:—(1) A comparison of the evidence on the strength of which the original discovery of the general theorem can be attributed to either the Greeks or the Indians; (2) A similar comparison as regards the knowledge of a general proof of the theorem; (3) The question of priority of knowledge of the general theorem among the ancient peoples; and (4) The grounds for crediting Pythagoras or the Indians with the first discovery of the irrational. The conclusions reached by Heath on the first two points are as follow:—He sees[2] "no sufficient reason to question the tradition that so far as Greek geometry was concerned Pythagoras was the first to introduce the theorem of I. 47 and to give a general proof of it"; as to the Indians, they had, he says,[3] "by trial in particular cases, persuaded themselves of the truth of the Pythagorean theorem and enunciated it in all its generality; but they had not established it by scientific proof." On the third point, without deciding the question of priority, he merely says:[4] "It must be admitted that Indian geometry had reached the stage at which we find it in Āpastamba quite independently of Greek influence." As regards the last point, he says nothing beyond mentioning[5] the tradition which attributes the discovery of the irrational to Pythagoras, while he denies[6] any credit to the Indians on the ground that "the old Indian geometry was purely empirical and practical, far removed from abstractions such as the irrational".

It will be interesting to examine these conclusions somewhat closely by a reference to the actual material on which each is based; and in doing so I shall confine myself in this article to the first three of the points stated above, reserving the fourth for some future occasion.

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[1] Heath, *Thirteen Books of Euclid's Elements*, Vol. I, pp. 350-364.
[2] Ibid, p. 351.
[3] Ibid, p. 364.
[4] Ibid, p. 364.
[5] Ibid, p. 351.
[6] Ibid, p. 364.

In his *Manual of Greek Mathematics* (pp. 95, 96), Heath himself has summarised all the grounds on which he is disposed to uphold the claim of Pythagoras to the discovery of the theorem. The whole passage in which he does this is quoted below:

> "Tradition is unanimous in referring to Pythagoras the discovery of the theorem of the square on the hypotenuse, but the documentary evidence is far from conclusive. Callimachus speaks of the 'figure' discovered by Pythagoras, and the distich of Apollodorus the 'Calculator' or mathematician (date uncertain) says, 'when Pythagoras discovered that famous proposition on the strength of which he offered a splendid sacrifice of oxen'. Unfortunately, neither author says what the proposition he refers to actually was. But Plutarch, Athenæus, Diogenes Laërtius, and Porphyry all connect the story of the sacrifice with the theorem of the square on the hypotenuse, though Plutarch, in giving Apollodorus' verses, expressed doubt whether the proposition referred to is that theorem or a certain problem of 'applying an area', while in another passage he says that the occasion of the sacrifice was the solution of the problem 'given two (rectilineal) figures to apply (he should rather have said 'construct') a third which shall be equal to the one and similar to the other'. Vitruvius, however, a century or so before Plutarch, definitely connected the sacrifice with the discovery that the particular triangle 3,4,5 is right-angled. Proclus will not commit himself to a definite opinion; he says, 'If we listen to those who wish to recount ancient history, we may find some of them referring this theorem (Euc. I, 47) to Pythagoras and saying that he sacrificed an ox in celebration of his discovery. But, for my part, while I admire *those who* first observed the truth of the theorem, I marvel more at the writer of the Elements, not only because he confirmed it by a most lucid demonstration, but because he compelled assent to the still more general theorem in the sixth book by the irrefutable arguments of science.' *It is difficult for us to be more positive than Proclus was; but for myself I like to believe that, so far as the general theorem and the truth of it are concerned, the commonly accepted tradition is right.*" (The italics in the concluding portion are mine.)

It will be observed that the whole of the above argument is but the usual story of how tradition weaves a continually growing web of achievements round a great name of antiquity. Callimachus and Apollodorus, the earliest of the authorities, mention no theorem; Vitruvius (14 B. C.) mentions the discovery as that of a particular case: Plutarch (120 A.D.) wavers between two theorems; and later, Athenæus (250 A.D.), Diogenes Laërtius (250 A.D.), and Porphyry (300 A.D.) begin definitely to connect the discovery with the general theorem of the square on the hypotenuse. Under these conditions it is no wonder that little credence could be given to the whole story even by Proclus (410–485 A.D.), one of the two authorities, (the other being Pappus, 4th century, A.D.) on whose works we have mainly to depend for all that we know of ancient Greek mathematics.

With the above evidence in support of Pythogoras' claim, we shall now proceed to compare and contrast that on which the Indians' claim is based. It may be observed at the outset that it is not any want of knowledge of the principal documentary or other material on which the Indian claim is based, which prevents Western scholars from recognising it to its fullest extent. Thus, it will appear from Heath's note on the subject that he either accepts or sees no reason to question the correctness of the following facts :—

(1) That in the Āpastamba Ṣulvasūtra, a treatise on the construction of sacrificial altars of different shapes, there is given a general enunciation of the theorem in question in the form[1], "The diagonal of a rectangle produces (*i. e.* the square on the diagonal is equal to) the sum of what the longer and the shorter sides separately produce (*i. e.* the squares on the two sides)."

(2) That this general enunciation is accompanied by several applications of the theorem to general constructions, such as the construction of the sum or difference of two squares and transformation of a rectangle into a square and *vice-versa.*[2]

(3) That the treatise gives several constructions[3] of right angles by means of the rational triangles (3,4,5), (5,12,13), (8,15,17) and (12,35,37), and others derived from these.

(4) That the date of the Āpastamba Ṣ-s. is ***at least as early as*** the 4th or 5th century B.C. (which is Bürk's estimate of the date).

(5) That the Baudhāyana Ṣ-s. (which also contains the whole of the above subject-matter[4]) is considered by Sanskrit scholars to be older than the Āpastamba Ṣ.-s.

And, (6) That the subject-matter of Āpastamba's book (and for the same reason, Baudhāyana's also) "must have been much older than the book itself ".

As regards the enunciation in (1), I may point out, as observed by Dr. Thibaut,[1] that although the property of the right-angled triangle is expressed in it in terms somewhat different from those familiar to us, it is in essence the same as that contained in Euclid, Book I, 47.

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[1] *Vide* Āpastamba Ṣulba-Sūtram, (University of Mysore, Oriental Library Publications, Sanskrit Series, No. 73), p. 21. The sūtra giving the enunciation runs as follows :--

दीर्घस्याक्ष्णयारज्जुः पार्श्वमानी तिर्यङ्मानी च यत्पृथग्भूते कुरुतस्तदुभयं करोति ।

Baudhāyana gives the same enunciation with only दीर्घचतुरस्रस्य for दीर्घस्य; so also does Kātyāyana.

[2] Āpastamba Ṣ.-s—pp. 39, 41, 46 and 47.

[3] Āpastamba Ṣ.-s—pp. 75-82

[4] *Vide* Ṣulva-sūtra of Baudhāyana, edited by Dr. G. Thibaut in the Pandit,—Vol. IX and X. Adhyāya I, 48, 50-54.

As regards (4), (5) and (6), I shall show later that the limit assigned by Bürk to the date of the Āpastamba-Ṣulva-sūtra requires to be pushed back into the past by about 4 centuries. But even assuming Bürk's limit, it ought not to require any great stretch of imagination to allow a precedence of at least one century to Baudhāyana's Treatise over Āpastamba's and place the origin of the subject-matter of the former at least two centuries earlier than the book itself. For, as observed by Macdonell,[2] "in the ritual Sūtras we possess the ancient manuals which the priests used as the foundation of their sacrificial lore. Their statements are so systematic and detailed that it is possible to reconstruct from them various sacrifices without having seen them performed." It would then appear that we must assign to the subject-matter a date at least as early as the 8th or 7th century B. C., *i. e.* 3 centuries prior to the date assigned by Bürk to the Āpastamba Ṣ.-s. Now, Pythagoras is believed to have lived in the 6th century B. C. (569-500). Hence, so far as the discovery of the general theorem of the square on the hypotenuse is concerned (leaving aside the question of its proof), it is surely not an unreasonable (but perhaps the most likely) conclusion to draw from the facts given above, that (1) the Indians had already discovered the theorem and employed it for general geometrical constructions at the time when Pythagoras is believed to have lived, and that (2) even supposing Pythagoras to have independently discovered the theorem, (which is very doubtful), the priority of discovery as between the Greeks and the Indians, must be assigned to the latter.

The logical need of drawing the above conclusion seems indeed to have been realized by Heath himself as may be inferred from the manner in which his own conclusion[3] is worded: "that *so far as Greek geometry was concerned,* Pythagoras was the first to introduce the theorem of I. 47 . . . . ". Here he admits the possibility of the discovery having been anticipated in India or elsewhere, while the word 'introduce' would cover both possibilities, *viz.*, Pythagoras' having discovered the theorem himself or his having obtained its knowledge from others. Further, while referring to Bürk's view that the theorem cannot be found anywhere so early as in India, Heath only points out the possibility of its being known earlier in Egypt. And yet he no-where allows himself to admit definitely the priority or even the simultaneity of the discovery of the theorem by the Indians so far as the Greeks are concerned, while the fact, that immediately after making the above statement he proceeds to say[1], "On this assumption, how was Pythagoras led to this discovery?", shows that he understands the word 'introduce' in the sense of 'discover'.

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[1] Dr. G. Thibaut—On the Ṣulva Sūtras—in the Journal of the Asiatic Society of Bengal, Vol. XLIV, pp. 232–234.

[2] A. A. Macdonell, *History of Sanskrit Literature*, p. 38.

[3] Heath, Euclid's Elements, Vol. I, p. 351.

In view of the general hesitation of Western scholars (with a few exceptions) to pronounce a definite opinion in favour of the Indian claim, it is necessary to make a few observations on the genesis of the study of Mathematics among the Indians.

The need for geometrical and mathematical investigations arose in India out of the requirements of the sacrificial system.[2] This system was almost as old as the Vedas, and its general features and guiding principles are prescribed in the White Yajurveda, the Taittirīya and other Samhitās, and the Ṣatapatha and other Brāhmaṇas. It is impossible to over-estimate the importance of the sacrifice in the religious life of the ancient Indians. It was to be performed at the right time; so the stars had to be observed and the motions of the Sun, the Moon and the Planets had to be studied; this gave rise to the science of astronomy. During its performance the Vedic Mantras had to be repeated with the proper pronunciation and a correct understanding of their import; this led to the study of phonetics on the one hand and that of grammar and etymology on the other. Again, the sacrificial fires and altars were to have the exact prescribed relative positions, shapes, areas and volumes, and they were to be constructed by using the prescribed number of bricks of specified shapes and sizes; all this required the study of geometry and methods of calculation. The investigations thus prompted into various branches of knowledge must have been carried on during the latter half of the Samhitā period and the Brāhmaṇa period. Their results, so far as they were required for sacrificial and other religious purposes, were embodied in the Sūtra or concise form in various manuals known as the Vedāngas. They give only the necessary principles, rules and directions, leaving the explanation or demonstration to be given by the teacher or the commentator. Of these Vedāngas, those most concerned with the ritual of Vedic sacrifices are the Kalpa manuals which include the Ṣrauta, Gṛihya and Dharma Sūtras. The Ṣulva-sūtras which concern themselves with the arrangement and construction of the various fires and altars are chapters in the Ṣrauta Sūtras or supplements thereto. Of these there are three, *viz.* those of Baudhāyana, Āpastamba and Kātyāyana.

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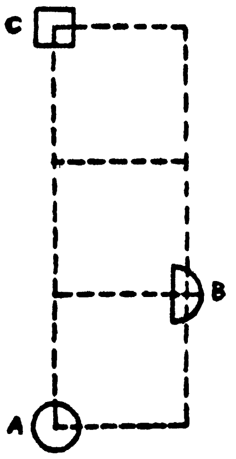
1. Heath, Euclid's Elements, Vol I, p. 352.
2. *Vide* Dr. Thibaut—On the Ṣulva Sūtras, J. R. A. B., Vol. XLIV.

A general idea of the principles of geometry required for the construction of the various fires and altars prescribed by the Vedas for different kinds of sacrifices will be obtained from the following brief description. The three sacred fires, Gārhapatya, Dakshiṇāgni and Āhavaniya, were always to have equal areas, but their shapes according to one precept[1] were to be respectively circular, semi-circular and square, and the relative positions of their centres were to be determined with respect to three equal squares drawn touching one another from west to east, (as shown in Fig. 1). Various shapes were prescribed for the fires for various purposes:—the Ṣyenachit, having the form of a falcon with straight or curved wings (see Fig. *2a* on the opposite page); the Kankachit, having the form of a heron; the Kūrmachit, having the form of a tortoise; the Praugachit, having the form of an isosceles triangle; the Ubhayatah–Praugachit, having the form of a rhombus; the Rathachakrachit, having the form of a wheel, with or without spokes; and so on. Whatever the form however, the measure of the area of the fire was always to be the same, *viz.*, 7$\frac{1}{2}$ square purushas. (One purusha = 120 angulis or finger-breadths ordinarily). When, for a special purpose, the actual size was to be increased, say by 12 square purushas, (as in the case of the thirteenth Agni in the Soma-sacrifice), the purusha-length itself was increased in the ratio $\sqrt{5} : \sqrt{13}$ by means of geometrical constructions, so that the measure of the area of the altar in terms of the square on this new purusha still remained 7$\frac{1}{2}$,



A—Gārhapatya Fire
B—Dakshiṇagni Fire
C—Āhavanīya Fire

When AC = 240 angulis,
diameter of A = 24 angulis,
diameter of B = $34\frac{5}{17}$ angulis,
side of C = $21\frac{9}{34}$ angulis.

FIG 1

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[1] Baudhāyana Ṣ.—s., II 61, व्यायाममात्री भवतीति गार्हपत्यचितेर्विज्ञायते ।, 62, चतुरस्रेत्येकेषाम् ।, 63, परिमंडलेत्येकेषाम्.

Also see commentary of Dwārakānāthayajvā on I, 60:—पृथिवीसंस्तवान्मंडलाकृतिर्गार्हपत्यः ।...अन्वाहार्यपचनः । अंतरिक्षसंस्तवाद्धनुराकृतिः ।...द्युलोकसंस्तवाच्चतुरस्रमाहवनीयः ।.

and its shape also remained the same, as at the beginning.[1] Every altar was to consist of 5 layers of bricks, each layer consisting of 200 bricks and the arrangement of bricks in alternate layers being such that one brick was never to lie upon another of the same size and form.[2] (See Fig. *2b* and *2c.*) The total height of the five layers was to be a Jānu, the height of the knee (= 32 angulis) this height being of course varied when the Purusha-length was varied. The bricks to be used in the construction were to be of prescribed dimensions and of different shapes, such as squares, oblongs, rhomboids, trapezia, right-angled triangles, etc., and combinations of these figures. Sometimes again a subsidiary vedi or altar was to be built whose area was to be a given fraction of another vedi; as for instance the Paitṛikī Vedi was to be a ninth part of the Saumikī Mahāvedi, and its form was

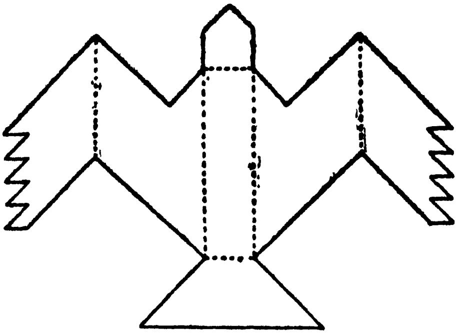

FIG. 2*a*

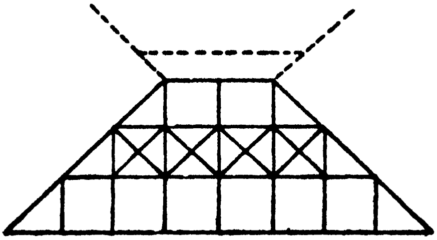

FIG. 2*b*

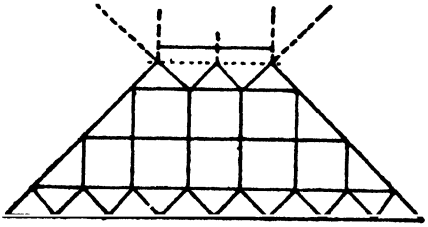

FIG. 2*c*

Fig. *2a*—Vakrapaksha Ṣyenachit (Falcon-shaped Fire).
Fig. *2b*—Arrangement of Bricks in the Tail, First Layer.
Fig. *2c*—Arrangement of Bricks in the Tail, Second Layer.

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[1] Baudhāyana Ṣ.-s.—II, 12:
यदन्यत्प्रकृतेस्तत्पञ्चदशभागान् कृत्वा विधायां विधायां द्वौ द्वौ भागौ समस्येत्ताभिरर्धाष्टमाभिरग्निं चिनुयात्।
Vide also Āpastamba Ṣ.-s.—III, 6:
अष्टविधप्रभृतीनां यदन्यत्सप्तभ्यस्तत्सप्तधा विभज्य प्रतिपुरुषमावेशयेत्।; आकृतिविकारस्याश्रुतत्वात् 'पुरुषमात्रेण विमिमीते' . . . ।

[2] Baudhāyana Ṣ.-s.—II, 26.
साहस्रं चिन्वीत प्रथमं चिन्वान इति। (Com. तत्र पञ्च चितयो भवन्ति 'तस्मात्पञ्चचितीकश्चेतव्य' इति वचनात्। ... द्विशतः प्रस्तारः... ।)
Also II, 22, भेदान् वर्जयेत्।; 23, अपरोत्तरयोः पार्श्वसंधानं भेदा इत्युपदिशन्ति।.

to be a square with one diagonal perpendicular to the parallel sides of the Mahāvedi which had the form of a trapezium.[1] (See Fig 3 on p. 100.) These are only a few of the various details of construction given in the Ṣulva-sūtras, and founded on definite directions given in the still older literature of the Samhitās and Brāhmaṇas, such as the Taittirīya Samhitā and Brāhmaṇa and the Śatapatha Brāhmaṇa.

It will be seen from the above brief description that it was not a small amount of geometrical knowledge, both theoretical and practical, that was required for the various constructions involved in the preparation of the sacrificial ground with its fires and altars. The priests who directed the constructions must know how, in the first place, to determine the east-west line. This[2] was done either by observing the star Krittika at its rising, or by observing the places on a circle where the shadow of a gnomon fixed in its centre crossed it in the morning and the afternoon. The east-west line being determined by joining these places, they must know how to draw a straight line at right-angles to another, in order to determine the north-south line. This construction was effected either by means of circles or by means of rational right-angled triangles. After these initial constructions, they must know how to construct a square or an oblong of given sides, a trapezium with given parallel sides and given perpendicular distance between them, isosceles and other triangles of given sides, rhombuses and rhomboids of given shapes and magnitudes, etc. They must also know how to construct a square equal to the sum or difference of two squares, how to transform a square into an oblong or an oblong into a square, how to transform a square or an oblong into a trapezium or a trapezium into a square or an oblong, how to construct a square or an oblong, equal to a fraction or multiple of a given figure, and so on. They were further required to know how to construct a square equal in area to a circle (*i. e.* to square a circle) and a circle equal in area to a square, how to construct a circle of twice the area of

[1] Baudhāyana Ṣ.—s.—I, 81, 82, 84 ;

81, वितृतीया वेदिर्भवतीति पैतृक्या वेदेर्विज्ञायते। ; 82, महावेदेस्तृतीयेन समचतुरस्रीकृतायास्तृतीयकरणी भवतीति नवमस्तु भूमेर्भागो भवति। ; 84, दिक्षु स्रक्तयो भवन्ति। .

[2] Baudhāyana in another place gives this method :—

कृत्तिकाः खल्विमाः प्राचीं दिशं न परिजहति। तासां संदर्शनेन मापयेत्.... ।

Kātyāyana gives the alternative method as follows :—

समे शंकुं निखाय शंकुसंमितया रज्ज्वा मंडलं परिलिख्य यत्र लेखयोः शंकग्रच्छाया निपतति सा प्राचीति।

another circle, how to increase the area of any irregular figure by a given amount, without disturbing its shape, etc. In all this knowledge of the ancient Indian priests, it is impossible not to recognize the fundamental character of the part played by the theorem of the square on the hypotenuse and also by the principle of similarity leading to the fact that the areas of similar figures are in the ratio of the squares on their corresponding sides.

On the high antiquity of all this knowledge, Dr. Thibaut[1] observes: "Whatever the period may have been during which Kalpasūtras and Ṣulvasūtras were composed in the form we have now before us, we must keep in view that they only give a systematically arranged description of sacrificial rites which had been practised during long preceding ages. The rules for the sizes of the various Vedis, for the primitive shape and variations of the Agni, etc., are given by the Brāhmaṇas although we cannot expect from this class of writings explanations of the manner in which the manifold measurements and transformations had to be managed. Many of the rules which we find now in Baudhāyana, Āpastamba and Kātyāyana, expressed in the same or almost in the same words, must have formed the common property of all adhvaryus long before they were embodied in the Kalpasūtras." When we remember that the elaboration of the sacrificial system had taken place long before the time of Buddha (500 B. C.) and that the Kalpasūtras must have been in constant use as handbooks for the use of priests before the time when he raised his revolt against the Vedic religion and its priestcraft, we shall not be guilty of any exaggeration, if we assert that the *general theorem* of the square on the hypotenuse had been discovered in India and applied for various geometrical *constructions of a general nature*, several centuries before the time when Thales and Pythagoras are supposed to have laid the foundation of the study of mathematics in Greece.

The above genesis of the study of mathematics in ancient India has also a bearing on the question of the possibility of the Indians having discovered a general proof of the theorem in question and of their capability to do so. For all this knowledge of the properties of various kinds of geometrical figures, their shapes and different manipulations with them could not have been in constant exercise by the Indian priests during century after century from the times of the Taittirīya Saṃhitā and the Ṣatapatha Brāhmaṇa and even earlier days to the times of Buddha when Vedic culture and religion received a check, without those priests having developed, by slow stages no doubt, a study of the principles involved in this knowledge and the necessary methods of measurement and calculation, apart from the mere practice of the rules. That they were capable of the highest kind of abstract reasoning is evidenced in the field of metaphysics by the Upanishad literature and in the field of scientific thought by the grammar of Pāṇini. In the case of grammar we are fortunate in having handed down to us a scientific text-book on the subject (written between 800 to 500 B. C.) and not merely a manual for the special purposes of Vedic ritual, such manuals on grammar being now lost. The mere fact, therefore, that in the case of geometry or general mathematics we possess at this time nothing more than manuals treating of the special requirements of Agnichayana or the construction of sacrificial altars, is no proof that the ancient Indians' knowledge of geometry was purely empirical and that it was far removed from abstract reasoning. It is indeed inconceivable that people who spent days after days in transforming the shapes and magnitudes of altars in given proportions and in the adjustment of thousands of bricks of different shapes so that a given number of them might fill a space of given shape should not have come across configurations which indicated a general proof of the theorem of the square on the hypotenuse so frequently used by them. As a matter of fact there are convincing indications in the Ṣulvasūtras, definitely showing that they must have secured such a proof. Before considering these, however, it will be desirable for the sake of comparison to examine the reasoning by which it is attempted to show that Pythagoras gave a general proof of the theorem.

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[1] G. Thibaut—On the Ṣulvasūtras,—J. A. S. B., Vol. XLIV, p. 270.

It seems indeed extremely strange that Western scholars should credit Pythagoras with having given a general proof of the theorem of the square on the hypotenuse when all the evidence that they have is based on the traditions which acquired definiteness only after the first century A.D., and when the Greek literature of the first five centuries after Pythagoras contains no reference to his having made the discovery of the theorem itself and much less, therefore, to his having discovered any general proof of it. But they put greater faith in these traditions, vague and of late origin as they are, than they would put in the documentary evidence afforded by the ancient Ṣulvasūtras of the Indians, and persuade themselves that Pythagoras must have discovered the theorem and given a general proof of it, by pursuing the following line of reasoning[1]:—Pythagoras is first assumed to have obtained from the Egyptians a knowledge of the fact that a triangle with its sides in the ratio 3,4,5 was right-angled. This, it is supposed, must have led him to consider whether a relation similar to $3^2+4^2=5^2$ was true of the sides of other right-angled triangles than the triangle (3,4,5); it is then assumed that the truth of the theorem in the case of an isosceles right-angled triangle must have appeared to him by some such method as that of the dissection of a square into parts by its diagonals. With his mind thus prepared by these two cases and perhaps some more, Pythygoras is presumed to have guessed the truth of the theorem in all cases. Now there being *no positive evidence as to how Pythagoras established the general truth of* the property, two possible lines are considered as open to him. One is a proof by means of proportion, it being assumed that the geometry of Pythagoras was sufficiently advanced to make it possible for him to prove the theorem by similar triangles, although no one has shown in what particular manner Pythagoras used such triangles. The other line is a proof by division into and re-arrangement of parts of a given square by some one or other of the well-known methods of dissection. Some Western scholars favour the first and some the second as the line most likely to have been followed by Pythagoras. This is all that we find in support of the assertion that Pythagoras gave a general proof of the theorem. The whole argument merely shows in what different ways a proof of the theorem can be obtained on the assumption, either of the theory of proportions as applied to similar triangles, being known to Pythagoras, or, of some kind of practical or theoretical need which induced him to study the division of squares into parts and the re-arrangement of these parts. But it gives not the least evidence, direct or indirect, which should enable us to assert that Pythagoras did follow some one of these ways and was the first to give a general proof of the theorem, whether scientific or otherwise.

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[1] Heath, *Thirteen Books of Euclid's Elements*, Vol. I, pp. 352–354.

If only a little of the spirit of making liberal assumptions in the case of the Greeks had been used by Western scholars in considering the claim of the Indians, they could easily have convinced themselves from the available evidence that the Indians who discovered the theorem of right-angled triangles could not but have obtained a general proof of it. But as we find, Heath allows himself on slender grounds to come to the conclusion that "the theorem is, it is true, enunciated (in Indian Geometry) as a general proposition, but there is no sign of anything like a general proof; there is nothing to show that the assumption of its universal truth was founded on anything better than an imperfect induction from a certain number of cases, discovered empirically, of triangles with sides in the ratio of whole numbers".[1] The only ground advanced for reaching this conclusion is that Āpastamba mentions only seven cases, really reducible to four, of rational rectangles, *i. e.* rectangles in which the sides and diagonal are in the ratios of integers. From this it is inferred that the Indians had not been able to formulate a general rule for finding any number of rational rectangles.´ This inference, untenable in itself, is surprising in the face of the fact admitted by Heath himself that among Āpastamba's constructions there were two which gave formulæ that could furnish any number of rational rectangles. Further it is difficult to see how, granting that Āpastamba had not formulated a general rule for finding rational rectangles, that fact would go against the Indians having obtained a general proof of the theorem of the square on the hypotenuse.

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[1] Heath, *Thirteen Books of Euclid's Elements*, Vol. I, p. 363.

The reason why Heath has been misled into thinking that Āpastamba knew of only seven rational rectangles is that he has not taken into account the context of Āpastamba's Sūtra quoted by him. The Sūtra is:—"Etāvanti jñeyāni Vedi-viharaṇāni bhavanti."[1] Heath translates it as "so many recognisable constructions are there", disregarding the word Vedi and adds that this implies that Āpastamba knew of no other rational rectangles. But the Sūtra ought to be translated as "so many recognisable constructions of the Vedi are there". The particular Vedi of which the construction in different ways is being described is the Saumikī Vedi.[2] (See Fig. 3).

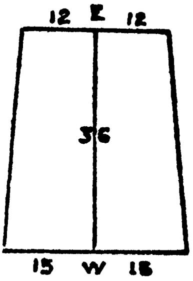

FIG. 3

Its form is that of a trapezium of which the two parallel sides are 24 and 30, the distance between them being 36, the oblique sides being symmetrically inclined. [Unit of length = 1 step = 15 finger-breadths.] The method[3] of construction is to draw first WE, the perpendicular distance between the parallel sides, of length 36; and then to draw at W and E the halves of the parallel sides first on the right and then on the left. These halves must be drawn of lengths 15 and 12 and must also be at right angles to WE. For this purpose it was convenient to use right-angled triangles, formed of chords, of which one side was 12 or 15. Āpastamba's list of constructions is made up of such triangles only and appears therefore to be what Heath calls 'meagre'. The triangles used by Āpastamba[1] are (12,16,20), (15,20,25), (5,12,13), (15,36,39), (8,15,17) and (12,35,37). These reduce to the four primary cases, (3,4,5), (5,12,13), (8,15,17) and (12,35,37) of right-angled rational triangles. It is noteworthy that these are the only possible primary cases which either themselves possess a side of length 12 or 15 about the right angle or yield other triangles of this description. This in itself is a strong indication of Āpastamba's being in possession of a general formula by means of which he could obtain any number of right-angled rational triangles from which to make a selection.

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[1] Āpastamba Ṣ.-s., I, 5, 8.

एतावन्ति ज्ञेयानि वेदिविहरणानि भवन्ति ।

[2] Āpastamba Ṣ.-s., I, 5. 1.

त्रिंशत्पदानि प्रक्रमा वा पश्चात्तिरश्चीति भवति । षट्त्रिंशत्प्राची चतुर्विंशतिः पुरस्तात्तिरश्चीति सौमिक्या वेदेर्विज्ञायते ।

[3] Āpastamba Ṣ.-s., I, 5, 2.

षट्त्रिंशिकायामष्टादशोपसमस्य अपरस्मादन्तादष्टादशसु लक्षणं पञ्चदशसु लक्षणं पृष्ठ्यान्तयोरन्तौ नियम्य पञ्चदशकेन दक्षिणापायम्य शंकुं निहन्त्येवमुत्तरतः श्रोणी । विपर्यस्तयांसौ पञ्चदशकेनैवापायम्य द्वादशके शंकुं निहन्ति । एवमुत्तरतस्तावंसौ ।

Let us now consider the indications afforded by the Ṣulvasūtras of the knowledge of a general proof of the theorem of the square on the hypotenuse. It may be observed that many of the constructions described in the Ṣulvasūtras carry with them their own immediately convincing proof. For, the method of transforming one figure into another or compounding two figures into one employed in the sutras is in general that of division into suitable parts and an appropriate readjustment of them (apachchhedya yathāyogam upadadhānam).

Thus, in transforming a rectangle into a square[2], Baudhāyana directs (see Fig. 4) that on the longer side AB($=a$), a length

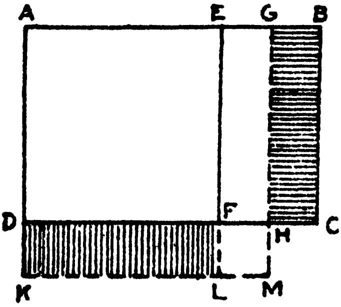

FIG. 4

AE should be marked off equal to the shorter side AD ($=b$), and the square AF completed; then the half GC of the rectangle EC should be cut out and applied to the side DF of the square AF, the other half EH remaining where it is; the space in the corner HFL being then filled with the square FM, the given rectangle AC is transformed into the difference of the squares AM and FM; this difference should then be transformed into a square by the method explained in a previous sūtra. (This construction, it may be noted, gives the formula:

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[1] Āpastamba Ṣ. s. pp. 75--82.

[2] Baudhāyana Ṣ. s. I, 54:

दीर्घचतुरस्रं समचतुरस्रं चिकीर्षंस्तिर्यङ्मानीं करणीं कृत्वा शेषं द्वेधा विभज्य विपर्यस्येतरत्रोपदध्यात् । खंडमावापेन तत्संपूरयेत् । तस्य निर्हार उक्तः ।

$$\left(\frac{a-b}{2}\right)^2+ab=\left(\frac{a+b}{2}\right)^2$$

from which any number of rational right-angled triangles may be obtained by putting $b=1$ and $a=n^2$).

So also, in transforming a rectangle into a trapezium[1] of the same height, we are directed (see Fig. 5) to measure off on the side AB of the rectangle AC a length AE equal to the shorter of the parallel sides of the trapezium, and then cutting out the triangle BEC, to apply it after reversal to the side AD.

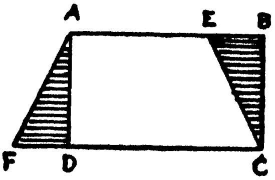

FIG. 5

Again, in transforming a square into a rectangle of given side,[2] (see Fig. 6,) we are to compound the side DC of the square with

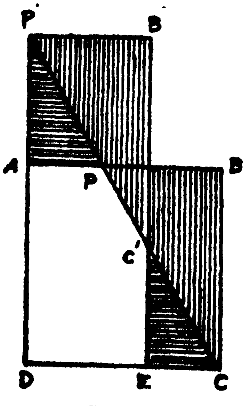

FIG. 6

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1. Baudhāyana Ṣ.-s. I., 55,

चतुरस्रमेकतोऽणिमच्चिकीर्षन्नणिमतः करणीं तिर्यङ्मानीं कृत्वा शेषमक्ष्णया विभज्य विपर्यस्येतरत्रोपदध्यात् ।.

2. Baudhāyana Ṣ.—s. I,53, [समचतुरस्रं दीर्घचतुरस्रं चिकीर्षन्] अपि चैतस्मिंश्चतुरस्रं समस्य तस्य करण्यापच्छिद्यायदतिशिष्यते तदितरत्रोपदध्यात्। Dr. Thibaut did not translate this sūtra as it did not clearly appear to him to what geometrical operation it referred.

DP′ taken along DA of length equal to the given side of the required rectangle, by joining CP′, which cuts off a part PBC from the square; this part being shifted into the position P′B′C′, and the space APP′ being then filled with CEC′ cut out, we get the required rectangle P′E.

It will now be seen how frequently this method of apachchhedanam (division) and yathāyogam upadadhānam (appropriate readjustment) is used in the constructions. When therefore a Sutra does not fully or explicitly describe its application, in any particular case, it will not be a far-fetched inference to take the application as implied therein. In the case of the composition of two squares,[1] (see Fig. 7), say ABCD and DEFG, Baudhāyana's construction is first to mark off in the larger square ABCD a rectangle ABHK with AK equal to the side of the smaller square, and then on the diagonal BK of this rectangle to describe a square. Now it is obvious that the smaller square DF being placed as in the figure, touching the larger one AC, we have merely to cut out the pieces KAB and KGF and apply them to the sides EF and BC respectively to get the square on BK, which is thus immediately seen to be equal to the given squares. It is more than probable that it was thus that the Indian priests proved the truth of the theorem, and this simple and natural method handed down from the past is found preserved practically in the same form in the works of later writers such as Bhāskarāchārya.

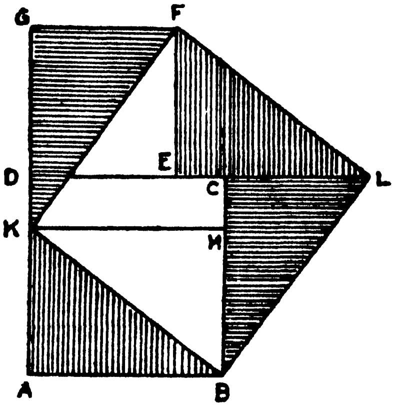

FIG. 7

As to the time when the Şulvasūtras were composed, it has been already mentioned that Bürk assigns to the Āpastamba Şulvasūtra a date at least as early as the 5th or 4th century B. C. This limit, as has been already observed, requires to be shifted back into the past by at least four centuries. The estimates of Western scholars regarding the dates of all kinds of ancient Indian Literature are considerably vitiated by the tenacious hold which Max Müller's purely arbitrary determination of the Vedic epochs has exercised over their minds. In this determination Max Müller[1] excludes the Vedānga or Sūtra literature from the pre-Buddhist Vedic literature of India, assigning to it the period from 600 to 200 B. C., while he compresses the whole of the literature consisting of the Samhitās, the Brāhmaṇas and the Upanishads into the short space of the period from 1200 to 600 B. C. This view of the antiquity of the Vedic literature of India was advanced by him purely as a hypothesis, in 1859. But, in the course of years since then, "it received" as observed by Winternitz,[2] "more and more the dignity and the character of a scientifically proved fact without any new arguments or actual proofs having been added". For a long time it was in vain that Indian scholars, like Dr. Bhandarkar, pointed out the fallacies in the procedure adopted by Max Müller. They received scant attention from Western scholars whose bias in favour of Greek civilization makes it difficult for them even to conceive of a much earlier antiquity for Indian civilization. Recently things have begun to improve. The date of Pānini which plays an important part in determining the period of the Sūtra literature, was assumed by Western scholars to be about 300 B. C., *i.e.*, the middle of the Sūtra period. It was shown by Bhandarkar that Pānini must be placed before Buddha, *i.e.*, before 500 B. C. at the latest. This view was further supported by the researches of Kunte, Rajavade, Vaidya, and other Indian scholars. Vaidya[3] has recently proved almost beyond doubt that Pāṇini cannot be assigned a date later than 800 B. C. The result of all this research has been that some Western scholars such as Winternitz have now begun to admit that Pāṇini cannot be placed after Buddha, *i.e.* after 500 B. C., that Buddha and Buddhistic literature presuppose the completion of the entire Vedic literature including the Vedāngas,[4] and that the end of the development of this (the Vedic) literature must be placed somewhere between 750 and 500 B. C[5]. As a consequence, 1200 or 1500 B. C. is found to be too late a starting point for the development of the whole Vedic literature from the Samhitās to the Sūtras, and Winternitz has thought it necessary to place the starting point at about 2000 or 2500 B. C.

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[1] Baudhāyana Ş.-ṣ. I, 50,

नानाचतुरस्रे समस्यन् कनीयसः करण्या वर्षीयसो वृध्रमुल्लिखेत्। वृध्रस्याक्ष्णया रज्जुः समस्तयोः पार्श्वमानी भवति।.

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[1] Max Müller—*History of Ancient Sanskrit Literature*, 1859.

[2] M. Winternitz-*A History of Indian Literature* (Calcutta University), Vol. I, pp. 292-293.

[3] C. V. Vaidya—*History of Sanskrit Literature*, Vedic Period, Vol. I, Sect. 3, pp. 146-160.

[4] Winternitz—*History*, Vol, I, p. 303.

[5] Winternitz—*History*, Vol. I, p. 310.

Further the researches of Dikshit and Tilak in India and those of Jacobi in Europe, based on some astronomical data supplied by Vedic literature have shown, with reasonable certainty, that the Vedānga-jyotisha was composed about 1300 B.C., that the Ṣatapatha Brāhmaṇa must have been composed some time between 3000 and 2000 B.C., and that parts of the Ṛigveda belong to a period not later than 4000 B.C.

Taking Winternitz' determination, 2500 to 750 B.C., of the period of development and completion of the entire Vedic literature including the Sūtra literature, we may reasonably assign the period 1250 to 750 B.C. to the Sūtra literature. It has been pointed out that Ṣrautasūtras which include the Ṣulvasūtras must be the oldest of Sūtra works, as they directly treat of the sacrificial ritual. It follows that we must assign to the Ṣulva-sūtras a date at least as early as 1000 B.C., and to their subject-matter a date several centuries earlier. Further, the construction of a right angle by means of cords of lengths 15,36,39, forming a right-angled triangle, is mentioned in works as old as the Taittirīya Samhitā and the Ṣatapatha Brāhmaṇa,[1] to which a date not later than 1500 B.C. may be assigned in accordance with Winternitz' general estimate, but which according to Indian scholars cannot be placed later than 2000 B.C. What is remarkable however is not the mere reference to a particular case of a rational right-angled triangle, but the fact that the Ṣatapatha Brāhmaṇa[2] mentions the increase by one square Purusha of the falcon-shaped seven-fold Agni for each subsequent sacrifice, up to the hundred-and-one-fold Agni, insisting also upon the general proportions remaining unchanged. The composition of two or more squares into one was thus an essential requirement of the construction of altars even in the days of the Brāhmaṇas and cannot be effected without a knowledge of the general method. It appears therefore necessary that we should date a knowledge of the general theorem of the square on the hypotenuse from a time even earlier than 1500 or 2000 B.C., in India.

In China, the earliest reference to the property in question is in connection with the triangle (3,4,5). It occurs in a work called Chou-pei which is said to be the oldest mathematical work left by the ancient Chinese. The dialogue which contains the reference took place between the sage-prince Chou-Kong and his learned minister Shang Kao, both of whom lived in the 12th century B.C. Mikami[3] the historian of Chinese Mathematics observes that the date of com-

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1. Ṣatapatha Brāhmaṇa, III, 5, 5, 1 to 6.

2. Ṣatapatha Brāhmaṇa, X,1,8,18 :—तस्माद्‌ सप्तविधमेव प्रथमं विदधीतायैकोत्तरमैकशतविधात् । Also, X,1,8,15 :—या वा एतस्य सप्तमस्य पुरुषस्य संपत्सैवैतेषां सर्वेषां संपत् ।.

3. Y. Mikami—*The Development of Mathematics in China and Japan.*

position of the work Chou-pei is unknown and "it is also questionable whether the whole of the book was composed at a single time or at several different times." There is no reference either in this work or any other Chinese mathematical work of date preceding 200 B. C. now extant, to the general theorem of the square on the hypotenuse. And yet Mikami asks,[1] "Pythagoras who flourished six long centuries later than Chou-Kong, is he not said to have travelled in the east to Babylon and perhaps farther on probably to India? Will it not be probable that he had seen the theorem that was destined to be connected with his name on his travel? Might he not have encountered it brought from China in some unknown way?"—questions which might be asked with far greater force by the Indians in behalf of their own ancient geometry.

As to the Babylonians,[2] it was only in 1928–29, that certain tablets were for the first time interpreted as containing mathematical problems, two of which are supposed to be based, in some form or another, on the property of the right-angled triangle, the particular case used being the triangle (12, 16, 20) which is equivalent to (3,4,5). Heath (on what grounds, it is not stated) believes the tablets to be as old as, "say", 2000 B. C. and concludes[3] that "the Babylonians of 2000 B. C. knew the property of the square on the hypotenuse of a right-angled triangle, at all events, in one case, that of a triangle with sides in the ratios of the numbers 3, 4, 5".

In the case of the Egyptians, it has been observed by Heath[4] in his latest work, *A Manual of Greek Mathematics,* that "the Egyptians indeed do not seem to possess it (*i. e.* knowledge of the property of right-angled triangles), for, although they knew that $3^2+4^2=5^2$, there is nothing in their mathematics, so far as known to us, to suggest that they knew that the triangle (3, 4, 5) is right-angled." Cajori,[5] however, argues from the word *harpedonaptae,* meaning "ropestretchers," applied to Egyptian geometers, that this might point to the conclusion that the Egyptians of 2000 B. C. constructed right angles by stretching around three pegs a rope consisting of three parts in the ratio 3 : 4 : 5.

All the foregoing arguments and considerations lead us to the following conclusions regarding the knowledge of the theorem of the square on the hypotenuse of a right-angled triangle before the time of Pythagoras, *i. e.* before the 6th century B. C.

1. There is positive documentary evidence which proves that

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[1] Mikami—*Mathematics in China and Japan,* p. 7.

[2] Heath—*Greek Mathematics,* p. 96.

[3] ibid. p. 522.

[4] ibid. p. 96.

[5] Cajory—*History,* p. 10.

the Indians had certainly discovered the general theorem and applied it to various general geometrical constructions as early at least as 1000 B. C., and from which we may further infer that this knowledge of the general theorem was probably as old as 2500 or 2000 B. C.

2. The same evidence also points to the conclusion with the utmost degree of probability that the Indians had obtained a general proof of the theorem by the method of division of figures into parts and an appropriate readjustment of them, as early at least as 1000 B. C., this method being suggested by the peculiar requirements of the construction of altars and used by them in most of their geometrical transformations.

3. There is no evidence to show that any of the ancient peoples except the Indians had discovered or even known the general theorem before the time of Pythagoras; nor is there any evidence to show that any of the ancient peoples except the Indians knew of any particular cases of rational right-angled triangles other than the triangle (3, 4, 5), and those derivable from it; the Indians on the other hand can be shown by positive evidence to have known and used five independent cases of such triangles, (apart from their knowledge of the general theorem), as early at least as 1000 B. C., and there is positive evidence to show that their knowledge of such particular cases is as old as that of other peoples.

In his *History of Mathematics* (Vol. I, p. 72), Smith says about Pythagoras and his contact with the East, " In spite of the assertions of various writers to the contrary, the evidence derived from the philosophy of Pythagoras points to his contact with the Orient. The mystery of the East appears in all his teachings. His mysticism of numbers is quite like that found earlier in Babylon, and indeed his whole philosophy savours much more of the Indian than of the Greek civilization in which he was born." We have seen how vague and hypothetical is the evidence on which is based his claim to the discovery of the theorem that goes under his name as well as of a general proof of it. It seems therefore reasonable to trace whatever knowledge of the theorem he possessed to an Indian origin, and in fairness and justice to Indian geometry to call the theorem itself "The Indian Vedi-vihāra Theorem," in view of the important part played by the construction of altars in its discovery by the Indian priests.

THE BISECTION METHOD

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1. It is proposed to give below a short account of a well known method which is commonly employed in connection with a certain type of problem in elementary theory of functions. The method is fairly simple but it is remarkable how many interesting and important theorems can be proved with its help. It is believed that this article would be of particular use to students of the Infinitesimal calculus in the B. A. and B. Sc. classes, as no simple account appears to be available in the commonly used text-books.

2. In what follows we shall use the term *point* to denote a real number; similarly an *interval* denotes all real numbers lying between two real numbers, the interval being called closed if the end points are included. We shall use the notation (a, b) to represent a closed interval with a, b as end points, *i.e.* the set of all real numbers lying between and including a and b. With these definitions geometrical language may be freely used to discuss properties of the arithmetical continuum, as it may be translated into purely arithmetical language without difficulty.

3. The purpose of the bisection method is to start from a given property of an interval and by continual bisection to track down the origin of that property to the neighbourhood of one or more points of that interval. This will be recognised as a particular case of the well known method of fitting systems of nets to an interval which is described for instance in Hobson's *Theory of Functions of a Real Variable*, Vol. I, art. 51; or in Knopp's *Infinite Series.*

4. The properties in which we are interested in the application of this method are not the intrinsic properties of an interval, but its properties relative to something external to it. Further the method cannot be applied to all types of properties of an interval but only to such as possess the following two characteristics:

' (i) If the property is known to be possessed by ***any*** given interval (a, b), then it is necessarily possessed by ***at least one*** of the two intervals (a, c) and (c, b) into which (a, b) is divided by any point c between a and b.

(ii) If the property is possessed by an interval (a, b), then it is necessarily possessed by any greater interval extending beyond a, b on either side.

Illustrations :

(a) The property possessed by an interval, that a given function $f(x)$ is continuous in it, possesses characteristic (i) but not (ii).

(b) The property of an interval, that the oscillation in it of a given function exceeds a certain value k, possesses characteristic (ii) but not (i).

(c) The property of an interval, that a given function is not bounded in it possesses both the characteristics.

5. We shall now state and prove our main theorem, *viz.*

If a given closed interval (a, b) possesses a property P having both the characteristics of paragraph 4, then there exists at least one point α of that interval such that every neighbourhood of that point, however small, possesses that property.

Proof. Divide (a, b) into two equal parts (a, c) and (c, b), c being the midpoint of (a, b); *i.e.* $c = \frac{1}{2}(a+b)$.

Then since P possesses the characteristic (i), either (a, c) or (c, b) or both possess the property P. Let (a_1, b_1) denote that half which possesses P; or in case both halves possess it, let it stand for the left hand half; *i.e.* let (a_1, b_1) be identical with (a, c).

Divide (a_1, b_1) into two equal parts (a_1, c_1) and (c_1, b_1), c_1 being the midpoint of (a_1, b_1).

Then as before at least one of the two halves possesses the property P. Let (a_2, b_2) denote that half which possesses it; or in case both halves possess it let it stand for the left hand half; *i.e.* let (a_2, b_2) be identical with (a_1, c_1).

This construction can obviously be repeated any number of times; and after n such steps we obtain an interval (a_n, b_n) which still retains the property P.

Moreover

$$b_n - a_n = \tfrac{1}{2}(b_{n-1} - a_{n-1}) = \tfrac{1}{4}(b_{n-2} - a_{n-2}) = \ldots\ldots = \frac{1}{2^n}(b - a).$$

Now it can be easily seen that,

$$a \leqslant a_1 \leqslant a_2 \leqslant \ldots\ldots\ldots \leqslant a_n \leqslant \ldots\ldots < b.$$

i.e. the a's form an ascending sequence which is bounded above. Therefore a_n tends to an upper limit A say as n tends to infinity,

$$\text{where } a_n \leqslant A \leqslant b \qquad \ldots\ldots\ldots\ldots\ldots \quad (1)$$

Similarly the b's form a descending sequence which is bounded below by a.

Therefore b_n tends to a lower limit B say, as n tends to infinity,

where $b_n \geqslant B \geqslant a$ . . . . (2)

Now from (1) and (2) above,

$$B - A \leqslant b_n - a_n = \frac{1}{2^n}(b-a);$$

but the right hand side tends to 0 as n tends to infinity. Therefore A and B must be identical, equal to α say.

Then α is the required point.

For, since α is the upper limit of a_n, given ε_1, there exists N_1 such that $\alpha - a_n < \varepsilon_1$, when $n > N_1$,

i.e., $a_n > \alpha - \varepsilon_1$ " "

Similarly given ε_2 there exists N_2 such that

$b_n - \alpha < \varepsilon_2$, when $n > N_2$,

i.e. $b_n < \alpha + \varepsilon_2$ " "

Therefore if N be the greater of N_1 and N_2 we have,

$$\alpha - \varepsilon_1 < a_n < b_n < \alpha + \varepsilon_2 \text{ when } n > N.$$

i.e. (a_n, b_n) lies inside $(\alpha - \varepsilon_1, \alpha + \varepsilon_2)$ when $n > N$.

Now (a_n, b_n) possesses the property P for all values of n. Therefore, from 4 (ii) above, it follows that any neighbourhood $(\alpha - \varepsilon_1, \alpha + \varepsilon_2)$ of α possesses that property, ε_1 and ε_2 being perfectly arbitrary.

Therefore α is the required point.

6. The point α satisfying the required condition is not necessarily unique. It is so, if at *every* step *only one* of the two halves into which the interval (a_n, b_n) is divided possesses the property P. For at all steps, where both halves retain the property P, we might choose the right hand half for the next step without vitiating the argument; we would then arrive at an entirely different point β. Again by following different laws for the selection of successive intervals (at those steps at which a choice is possible) we should obtain different limiting points.

N. B.—If a choice is available at only *one* step, we do not necessarily obtain two different limiting points. This is clear if we consider what would happen if the limiting point coincided with the midpoint of the interval at which the choice is available.

7. We now consider some examples of the application of the Bisection method. . . . . .

Weierstrass's theorem. If a set of points S contains infinitely many points entirely situated in an interval (a, b), then at least one point of the interval is a point of accumulation of S.

(A point of accumulation is such that any neighbourhood of it contains infinitely many points of the set.)

Here the application of the method is direct; for a limiting point α obtained by starting with the property P of the interval that there are infinitely many points of the set S in it, is a point of accumulation of S.

More often the application is indirect being based on a "*reductio ad absurdum*" argument, as in the following example.

If a function $f(x)$ is continuous in the interval (a,b), it is possible to divide (a,b) into a finite number of subintervals such that the oscillation of $f(x)$ in each is less than a given number k.

For, if it is not so, let the property P be the *impossibility* of dividing the given interval into a finite number of subintervals the oscillation in each of which is less than k; and apply the bisection method.

We then come to the limiting point α such that it is impossible to divide any neighbourhood of it into a finite number of subintervals such that the oscillation of $f(x)$ in each is less than k. This is absurd.

For, since $f(x)$ is continuous in (a, b), it is continuous at α which belongs to the interval; and therefore given any number ε, however small, it is possible to find a neighbourhood of α such that $|f(x)-f(\alpha)| < \varepsilon$ when x belongs to that neighbourhood. Now take $\varepsilon = \frac{1}{2}k$. Then if x_1, x_2 are any two values of x in that neighbourhood, we have

$$\begin{aligned} |f(x_1)-f(x_2)| &\leqslant |f(x_1)-f(\alpha)| + |f(x_2)-f(\alpha)| \\ &< \tfrac{1}{2}k + \tfrac{1}{2}k \;. \end{aligned}$$

$$\text{or } |f(x_1)-f(x_2)| < k$$

i. e. the oscillation of $f(x)$ in that neighbourhood is less than k while the neighbourhood does not require to be divided at all. Therefore our supposition is not tenable and the proposition must be true.

The theorem that *a function continuous in a given interval is uniformly continuous in it* follows as an easy corollary of the above.

Among other theorems which can be proved by the bisection method, the following may be mentioned:

A function which is continuous in a given interval is also bounded in it.

If $f(x)$ is continuous in (a,b), and $f(a)$ and $f(b)$ have opposite signs, then $f(x)$ vanishes at least once in the interval.

(To prove this, apply the bisection method by taking P to be property: "$f(x)$ is both positive and negative at points of the interval." Then the function must vanish either at one of the points of bisection c_n for some value of n, or at the limiting point α.)

If a sequence S_n is bounded, it has at least one limiting point.

(Compare Weierstrass's theorem above.)

Cauchy's principle of convergence for sequences, *viz.*

"*A sequence S_n tends to a limit if given ε, it is possible to determine a number N such that $| S_m - S_n | < \varepsilon$ whenever m and n are both greater than N*"

follows as a consequence of the above, by showing that the existence of two limiting points is incompatible with the given condition.

8. The bisection method can easily be extended to two-dimensional intervals. If any finite two-dimensional area is continually divided into two by alternately taking the line of division parallel to the two axes of co-ordinates, we can easily show that each interval lies inside the preceding, and that they converge to a limiting point just as in § 5.

This extension enables us to obtain many analogues of the theorems of § 7 for functions of two variables.

Further extension to three or more dimensions is obviously possible but not of any great practical importance.

NOTE ON CONFOCAL QUADRICS

By

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The equation of any quadric confocal with the quadric given by the general equation of the second degree, *viz.*,

$$S \equiv (a, b, c, d, f, g, h, u, v, w, d)(x, y, z, 1)^2 = 0,$$

is

$$\begin{vmatrix} a+\lambda & h & g & X \\ h & b+\lambda & f & Y \\ g & f & c+\lambda & Z \\ X & Y & Z & S \end{vmatrix} = 0,$$

where λ is a parameter, and

$$X = \tfrac{1}{2}\frac{\partial S}{\partial x},\quad Y = \tfrac{1}{2}\frac{\partial S}{\partial y},\quad Z = \tfrac{1}{2}\frac{\partial S}{\partial z}.$$

The following is a method of obtaining the above result.

If the equation

$$(x-\alpha)^2+(y-\beta)^2+(z-\gamma)^2+\mu\left\{\frac{x^2}{a^2}+\frac{y^2}{b^2}+\frac{z^2}{c^2}-1\right\}=0$$

represents a cone, the condition is that

$$\begin{vmatrix} 1+\frac{\mu}{a^2} & 0 & 0 & -\alpha \\ 0 & 1+\frac{\mu}{b^2} & 0 & -\beta \\ 0 & 0 & 1+\frac{\mu}{c^2} & -\gamma \\ -\alpha & -\beta & -\gamma & \alpha^2+\beta^2+\gamma^2-\mu \end{vmatrix} = 0,$$

which reduces to

$$-\Sigma\alpha^2\left(1+\frac{\mu}{b^2}\right)\left(1+\frac{\mu}{c^2}\right)$$
$$+\left(1+\frac{\mu}{a^2}\right)\left(1+\frac{\mu}{b^2}\right)\left(1+\frac{\mu}{c^2}\right)\left(\alpha^2+\beta^2+\gamma^2-\mu\right)=0,$$

or $\quad \Sigma\alpha^2\Big/\left(1+\frac{\mu}{a^2}\right)=\alpha^2+\beta^2+\gamma^2-\mu,$

$$i.e.\ \Sigma\frac{\alpha^2}{\mu+a^2}=1,$$

so that the point (α, β, γ) must be a point on a quadric confocal with $\Sigma\, x^2/a^2 = 1$.

Using this result as a lemma, we write down the condition that the equation

$$\lambda[(x-\alpha)^2+(y-\beta)^2+(z-\gamma)^2]+S=0$$

may represent a cone. The condition is

$$\begin{vmatrix} \lambda+a & h & g & -\lambda\alpha+u \\ h & \lambda+b & f & -\lambda\beta+v \\ g & f & \lambda+c & -\lambda\gamma+w \\ -\lambda\alpha+u & -\lambda\beta+v & -\lambda\gamma+w & \lambda\Sigma\alpha^2+d \end{vmatrix}=0,$$

which can be easily reduced to

$$\begin{vmatrix} \lambda+a & h & g & \frac{1}{2}\frac{\partial S'}{\partial\alpha} \\ h & \lambda+b & f & \frac{1}{2}\frac{\partial S'}{\partial\beta} \\ g & f & \lambda+c & \frac{1}{2}\frac{\partial S'}{\partial\gamma} \\ \frac{1}{2}\frac{\partial S'}{\partial\alpha} & \frac{1}{2}\frac{\partial S'}{\partial\beta} & \frac{1}{2}\frac{\partial S'}{\partial\gamma} & S' \end{vmatrix}=0,$$

where $S' \equiv (a, b, c, \ldots .)(\alpha, \beta, \gamma, 1)^2$. Writing x, y, z, for α, β, γ respectively, we get the result in the required form.

A SHORT NOTE ON THE CONVENTIONAL EQUALITY OF MATRICES

By

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In section 2 of his monumental work on *Matrices and Determinoids*, Vol. I, Dr. C. E. Cullis has defined the unit matrix as a square matrix in which every element of the leading diagonal has the value 1 and every other element has the value 0 ; it is said to be of order m if the number of terms in each row be m. Further in section 39, the *conventional* equality of two dissimilar matrices is defined to be the equality of the two similar matrices to which the former matrices can be reduced by the addition of rows of 0's after the existing rows. Two matrices which differ only by final rows of 0's are by this convention, equivalent. For instance,

$$\left\{\begin{matrix}1 & 0\\ 0 & 1\end{matrix}\right\} = \left\{\begin{matrix}1 & 0 & 0 & 0\\ 0 & 1 & 0 & 0\\ 0 & 0 & 0 & 0\\ 0 & 0 & 0 & 0\end{matrix}\right\}$$

i. e., the unit matrix of second order is equal to a square-matrix of the fourth order. The latter, however, is different from the unit matrix of fourth order in that the two lower elements of the leading diagonal are zeros instead of unity. Thus the unit matrices of different orders are not equal, even conventionally ; this is an anomaly, for a given matrix should reproduce itself when multiplied by a unit matrix of any order. In other words all unit matrices should be equivalent. The object of the present note is to show that this object can be achieved by using a modification of the above convention, *viz.* by adopting the following convention in its place :

(i) A zero matrix is one in which every element is zero ; its rank is immaterial for all zero matrices are conventionally equivalent.

(ii) All unit matrices are equivalent.

(iii) A matrix $[a]^{m}_{n}$, of rank m, n can be reduced to another matrix of higher rank which would be conventionally equivalent to the former, by the addition of the requisite number of rows in which every *additional element* $a_{pq}=0$ unless $p=q$. The value of each element when $p=q$, is to be 1, if *all* the elements of the given matrix have no common factor; and it is to be k if these elements have k as their highest common factor.

It is easy to see that (ii) is a special case of (iii), and that (i) also may be regarded as such if we agree to consider 0 as a common factor. The conventions (i) and (ii) are stated separately and before (iii), not because they are more fundamental than (iii) but on account of their simplicity. It should not therefore be supposed that the equivalency has been achieved by the very simple process of assuming the same. The convention (iii) is the principal one and it is so chosen as not to alter the existing rules of operation on similar matrices or those of the multiplication of a matrix by a scalar number. Thus

$$\left\{\begin{matrix} k & 0 \\ 0 & k \end{matrix}\right\} = \left\{\begin{matrix} k & 0 & 0 \\ 0 & k & 0 \\ 0 & 0 & k \end{matrix}\right\} = \left\{\begin{matrix} k & 0 & 0 & 0 \\ 0 & k & 0 & 0 \\ 0 & 0 & k & 0 \\ 0 & 0 & 0 & k \end{matrix}\right\} = \text{etc.},$$

because the elements have a common factor k. If we multiply these matrices by the scalar number $1/k$, we get the convention (ii). Again

$$\left\{\begin{matrix} a_1 & b_1 \\ a_2 & b_2 \\ a_3 & b_3 \end{matrix}\right\} = \left\{\begin{matrix} a_1 & b_1 & 0 & 0 \\ a_2 & b_2 & 0 & 0 \\ a_3 & b_3 & 1 & 0 \\ 0 & 0 & 0 & 1 \end{matrix}\right\}$$

when the given a's and b's have no common factor; the elements 1 in the right-hand matrix are to be replaced by k, if k happens to be the H. C. F. of the a's and the b's.

Conversely, we can get an equivalent matrix from another by striking out any final horizontal (or vertical) row of the latter provided that the elements in the row are zeros excepting the one belonging to the leading diagonal, which should be 1 or k as the case demands.

I propose next to discuss a few simple modifications that the new conventions produce in the existing rules of operation. A discussion of other possible effects may be given in a subsequent paper. It is clear that the proposed convention will affect the rules relating to dissimilar matrices to which, therefore, we fix our attention.

Addition Rule.—The given matrices are first replaced by equivalent similar matrices, by adding extra rows of elements in accordance with the convention (iii). Let them be denoted by $[a]_n^m$ and $[b]_n^m$. Then

$$[a]_n^m + [b]_n^m = [c]_n^m$$

where the element $c_{pq} = a_{pq} + b_{pq}$ unless a_{pq} and b_{pq} are *both* additional elements (introduced to make the given matrices similar). In the latter case c_{pq} would be the H. C. F of the non-zero additional elements a_{pq} and b_{pq}; and $c_{pq} = 0$ if either a_{pq} or b_{pq} be zero. Similar would be the rule for subtraction.

The above is slightly more complicated than the existing addition rule. But it was to be expected, for, the mode of introduction of the various additional elements in the new convention shows that they may not all behave in the same manner. This is perhaps the drawback of the new convention.

Multiplication Rule.—The given matrices are first converted into equivalent ones of equal passivity; let them be denoted by $[a]^{r}_{n}$ and $[b]^{m}_{r}$. Then

$$[a]^{r}_{n} \times [b]^{m}_{r} = [c]^{m}_{n}$$

where $c_{pq} = a_{p1}\, b_{1q} + a_{p2}\, b_{2q} + \dots\dots = \Sigma\, a_{pj}\, b_{jq}$.

The values of the elements of the product but not the general rule of their formation is modified to some extent by the new convention.

For the sake of brevity let $M = \left\{\begin{matrix} a_1 & b_1 & c_1 \\ a_2 & b_2 & c_2 \\ a_3 & b_3 & c_3 \end{matrix}\right\}$. Then

$$M \times \left\{\begin{matrix} 1 & 0 \\ 0 & 1 \end{matrix}\right\} = M \times \left\{\begin{matrix} 1 & 0 & 0 \\ 0 & 1 & 0 \\ 0 & 0 & 1 \end{matrix}\right\} = M.$$

$$\text{Again, } \left\{\begin{matrix} a_1 & b_1 \\ a_2 & b_2 \\ a_3 & b_3 \\ a_4 & b_4 \end{matrix}\right\} \times \left\{\begin{matrix} p_1 & q_1 \\ p_2 & q_2 \\ p_3 & q_3 \end{matrix}\right\} = \left\{\begin{matrix} a_1 & b_1 & 0 \\ a_2 & b_2 & 0 \\ a_3 & b_3 & 1 \\ a_4 & b_4 & 0 \end{matrix}\right\} \times \left\{\begin{matrix} p_1 & q_1 \\ p_2 & q_2 \\ p_3 & q_3 \end{matrix}\right\}$$

$$= \left\{\begin{matrix} a_1\, p_1 + b_1\, p_2 & a_1\, q_1 + b_1\, q_2 \\ a_2\, p_1 + b_2\, p_2 & a_2\, q_1 + b_2\, q_2 \\ a_3\, p_1 + b_3\, p_2 + p_3 & a_3\, q_1 + a_3\, q_2 + q_3 \\ a_4\, p_1 + b_4\, p_2 & a_4\, q_1 + b_4\, q_2 \end{matrix}\right\}.$$

This matrix differs from the product given by the existing rules inasmuch as the latter does not contain the terms p_3 and q_3 in the third row. It follows that the old alternate method of calculating the product by first striking out the final redundant passive rows is not valid according to the new scheme.

It can be easily shown that if the given matrices be successively replaced by conventionally equivalent ones (of different ranks but having the same passivity) the products will be conventionally equivalent matrices.

The new rules introduce some interesting features when one of the matrix-factors is scalar or quasi-scalar. For example

$$\left\{\begin{matrix} k & 0 \\ 0 & k \end{matrix}\right\} \times M = \left\{\begin{matrix} ka_1 & kb_1 & kc_1 \\ ka_2 & kb_2 & kc_2 \\ ka_3 & kb_3 & kc_3 \end{matrix}\right\} = k \times M; \quad \ldots \quad (1)$$

whereas the old rules would have given the product simply as

$$\left\{\begin{matrix} ka_1 & kb_1 & kc_1 \\ ka_2 & kb_2 & kc_2 \end{matrix}\right\}$$

The effect of a scalar-matrix factor, as in (1), ought to be a simple multiplication of the other matrix by a scalar number. This is evident since

$$[k]^{m}_{m} = k\ [1]^{m}_{m}$$

Further $\left\{\begin{matrix} k & 0 \\ 0 & l \end{matrix}\right\} \times M = \left\{\begin{matrix} k & 0 & 0 \\ 0 & l & 0 \\ 0 & 0 & 1 \end{matrix}\right\} \times M = \left\{\begin{matrix} ka_1 & kb_1 & ko_1 \\ la_2 & lb_2 & lc_2 \\ a_3 & b_3 & c_3 \end{matrix}\right\}$

and $\left\{\begin{matrix} kp & 0 \\ 0 & lp \end{matrix}\right\} \times M = \left\{\begin{matrix} kp & 0 & 0 \\ 0 & lp & 0 \\ 0 & 0 & p \end{matrix}\right\} \times M = \left\{\begin{matrix} kpa_1 & kpb_1 & kpc_1 \\ lpa_2 & lpb_2 & lpc_2 \\ pa_3 & pb_3 & pc_3 \end{matrix}\right\}$

$$= p \times \left\{\begin{matrix} k & 0 \\ 0 & l \end{matrix}\right\} \times M$$

On the other hand the old rules would have altogether omitted the third horizontal rows in the results. It is desirable that the presence of a scalar or a quasi-scalar-matrix factor does not alter the rank of the other matrix factor; one can then utilise this fact in recognising the scalar character of such matrix-factors.

APPLIED CHEMICAL RESEARCH

By

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PART I. SOME GENERAL PRINCIPLES

Introduction

Research is so intangible that its systematic teaching is looked on as difficult if not impossible. The student is supposed to acquire the knack of "doing research" by working through a problem under the guidance of a Professor, who in an indefinite way communicates to the disciple the mysteries of the art. While this attitude may be justifiable, the present author holds that it is possible, particularly in the field of applied chemistry, to put down, although vaguely, some factors which assist success. No guarantee can be given that they will produce it, for research is on a par with the Turf and the Stock Exchange; a knowledge of the future is required before prognosis can attain certainty. And like all things which involve a gamble, there are almost as many opinions as gamblers, so that one who, not being an angel, ventures into print, risks the fate that waits on false prophets. The plunge being taken however, we assume initially that the worker wishes to begin some type of chemical development research and from this point of view we will consider some general principles which may assist him.

For our present purpose the various types of chemical development research may be classified broadly as follows:—

1. The production of a new product.
2. The production of an existing technical product by a new process.
3. The improvement of an existing process.
4. The transference of a known reaction from the laboratory to the technical scale.

The divisions of this classification may now be considered in greater detail.

1. *Production of a New Product*

The object of this type of research is to obtain a new substance which will command a large and ready market. This renders it necessary that the product should preferably be one satisfying a primary need of human nature, *e. g.*, a food, a clothing material, or a fuel, or that it should be an adjunct to the production of these necessities, *e.g.*, a fertiliser, an explosive or a structural material.

Since most of the simple combinations of the elements available in large quantities have been worked out, a new composition of matter capable of being manufactured on a large scale will probably be complex in structure. The raw materials may be complicated natural products available in quantity, as with artificial silk, or simpler materials which under suitable conditions readily form complicated substances; the synthetic resin industry may be quoted as an example.

Owing to the indefinite nature of the problems, work of this kind is difficult to initiate; probably the best method is to attempt to imitate a natural product with an assured market, *e. g.*, to make artificial leather. But even when initiated, chemical control is difficult, owing to the complicated nature of the product, and research of this kind is apt to become expensive both in time and money. When there is added the difficulty of finding a market for a new product and the cost of displacing related older products, it would appear that, in spite of the profits which wait on success, an instance of which is given by the artificial silk industry, research of this type is attractive only under special circumstances.

2. *Production of an Existing Technical Product by a New Process*

This type of research has a definite object and is, on that account, in general more attractive. Some great industries have originated through success in this field; synthetic ammonia, and ammonia-soda provide examples. Research of this kind, particularly when confined to the strictly chemical field, is readily initiated. The number of general chemical products with a world production of, say, over 500 tons per annum is limited; with a list of these products and with particulars of the present method of manufacture it is not difficult to choose processes which seem capable of replacement.

Fundamental Characteristics of New Processes for General Chemicals

A new process for a general chemical manufactured in any quantity will usually have two fundamental characteristics :—

(*a*). The raw materials will be readily obtainable and probably simple.

(*b*). A new process using simple materials will probably involve the application of a new set of external conditions.

The necessity for the ready availability of raw materials is obvious, since otherwise a large output is impossible. As regards simplicity of raw materials, the tendency of all modern general chemical processes is to use simple materials, *e. g.*, ammonia is synthesised from coal (considered as carbon), air and water, while methanol requires coal and water. Initially, these products were made by degradation of complex substances. Ethyl alcohol is still produced from starch, but even here the tendency is to base the manufacture on synthesis from simple materials.

These considerations apply particularly to countries in which conditions do not on the whole favour the growing of natural materials for degradation to simpler products. In other countries biological degradation methods may still be of importance.

If it is sought to base a new process on a gas reaction, in which field many of the recent successes of technical chemistry have been achieved, then the raw materials will certainly be simple and can be taken from a list of readily available gases and vapours such as given in Table 1.

TABLE 1

Industrial Gases and Vapours.

Elements. H_2, N_2, S_2, O_2, Cl_2.
Hydrocarbons. CH_4, C_2H_6, C_3H_8, C_4H_{10}, C_5H_{12}, C_6H_{14}, C_2H_4, C_3H_6, C_4H_8, C_5H_{10}, C_2H_2, C_6H_6.
Oxygen Compounds. CO_2, CO, H_2O, NO_2, NO, N_2O_5, N_2O_3, SO_2, SO_3, CH_3OH, C_2H_5OH, CH_2O, $HCOOH$, CH_3COOH, C_6H_5OH.
Nitrogen Compounds. NH_3, N_2H_4, NH_2OH, HCN.
Chlorine Compounds. $COCl_2$, HCl, $SOCl_2$, SO_2Cl_2.
Sulphur Compounds. H_2S, CS_2.

All important industrial gas reactions may be obtained by a suitable choice of reagents from the table, so that future lines of work can be deduced in the same way.

Since most of the synthetic chemicals of which the output is in any way large are simple derivatives of the raw materials, the number of operations to which the raw materials will be subjected will usually be small. The necessity of achieving a new result from simple materials in a few operations indicates that the conditions to which these raw materials will be subjected must be different from those usually employed in chemical practice. Owing to the amount of work which has been carried out on simple materials in the laboratory it is now difficult to get a new result in a simple way. The success of the synthetic ammonia process lies in the fact that a new method of working (high pressure with suitable catalysts) was applied to the simple raw materials, hydrogen and nitrogen, to give a simple product, ammonia.

As a general rule, therefore, with a new process the complication will lie in the conditions to which the raw materials are subjected, rather than in the raw materials or the number of operations.

Variables which control External Conditions

The variables which control the external conditions may be tabulated as follows :—

A. Pressure
B. Temperature
C. Electrical external conditions
D. Other external conditions.

A. Pressure

The effect of high pressure on chemical reactions has been intensively investigated during the past few years. This method of working has the advantage that condensation reactions involving synthesis from simple materials will usually be facilitated. At present industrial technique puts a limit to the pressure which can be employed on a manufacturing scale, but there is little doubt that as it becomes possible to use pressures of the order of a thousand atmospheres and upwards new reactions between simple materials will be discovered. It would seem advisable to investigate in the laboratory the effect of heat on a few simple substances or mixtures of simple substances at these hyper pressures. Even at 500 atmospheres which is a pressure within the range of immediate practical attainment there is a possibility of new reactions being discovered.

Work at pressures below atmospheric is not so attractive industrially but might lead to interesting results.

B. Temperature

This is the variable which has been mostly employed to control reaction between substances. Nevertheless gaseous reactions at high temperatures, apart from fuel reactions, have not been used to any extent in industry. Their application presents difficulties but it is probable that as refractory technique improves such high temperature gas reactions will become important, particularly in the production of substances with a high energy content, which are at present obtained by electrical means and are therefore expensive to make.

Although primarily applicable to endothermic reactions, recent research has shown that interesting new results can be obtained by carrying out exothermic reactions at high temperatures. This is a field which, so far, has received little attention.

Turning to the other end of the scale practically no work has been carried out on reactions at low temperatures. This field is limited owing to the fact that the number of reactions which will proceed below 0°C. is few. Reference may be made to the reaction between ethylene and chlorine which has been found to give better yields of ethylene chloride when the temperature is reduced and the reaction is carried out in the liquid phase. Since liquefied gases are now available in large quantities this type of reaction should not be completely neglected.

C. *Electrical External Conditions*

The fact that many reactions, especially those which involve a large absorption of energy and are otherwise difficult to effect, can be performed in an electric field, has led to much time being devoted to research of this nature. So far little commercial success has been obtained. Few of the nitric oxide arc plants are now functioning, and attempts to manufacture acetylene from methane in this way have had no permanent success. It is stated, however, that an arc process for the production of hydrogen cyanide from oil gas and nitrogen is now working in Poland. As electrical power becomes cheaper, reactions of this type may become important, particularly when the temperature and pressure variables are introduced.

Magnetic fields have not yet been found to be of importance in controlling chemical reactions.

D. *Other External Conditions*

The variables here introduced are less well defined than those considered above. An example of variation in an external condition other than one already treated is given by change of solvent. The commercial use of liquid ammonia or liquid sulphur dioxide in this connection does not seem to have been examined in any detail.

The effect of catalysts may be considered here. The field for catalytic research is unlimited, but owing to the difficulty, in the present state of our knowledge, of predicting the effect of a given catalyst on a reaction, work in this direction tends to become a matter of trial and error as far as applied research is concerned. There is on the other hand, much scope for purely scientific work in examining, for example, the effect of a wide range of substances on the progress of one simple reaction.

Reference may here be made to the possible applications of the photo-chemical activation of mixture of gases, and to the use of mercury vapour as a carrier of photo-chemical energy.

3. *Improvement of Existing Process*

This type of research requires a specialised knowledge of the process under examination and is, on that account, best carried out by a research staff attached to the process. It is impossible to generalise the methods to be employed except that it might be expected that it will be in those stages of the process in which the energy changes involved are the greatest, that the best opportunities for improvement will occur.

4. *Transference of a Known Reaction from the Laboratory to the Technical Scale*

Two forms of this type of reaction may be distinguished. In the one, a processs worked elsewhere is studied for a short time in the laboratory and then on a semi-technical scale before proceeding to the design of a full-scale plant. In the second a known laboratory method of preparation is investigated with a view to manufacturing in the same way a product which has not been marketed before. The former type of research calls for no special comment; the latter is one which has been greatly exploited in the United States during the past few years. Several chemicals previously of laboratory interest only, *e. g.* ethylene oxide, and diphenyl, have been put on the market there. In England the considerable difficulty which appears to be encountered in creating markets has not encouraged this type of research, and it seems preferable there to concentrate on new methods for older products which already possess a certain market.

PART II

SOME PARTICULAR APPLICATIONS

The subject treated in Part I is considered below in more detail. There are described some possible lines of attack on the problem of deriving a new process for a known chemical.

Before a new process is sought the various laboratory methods which have been employed for the product in question should be examined, and their suitability for large-scale work considered. Any prior process which has been employed for the product in question must be studied to determine if any change in economic or chemical conditions render a reconsideration of its use necessary.

As an example during the War an increase in the demand for phenol above that which could be obtained from coal tar led to the laboratory method of preparation from benzene through benzene-sulphonic acid being put on to the large scale. Many of these synthetic phenol plants have since been closed down in England but a rapid increase in the market for synthetic resins might render the process again economic if no further source of phenols became available.

Again a fall in the price of aniline and nitrous acid and an increase in that of phenol might render the laboratory method for the production of phenol from aniline attractive for large-scale working.

When prior work on the production of a product has been examined the following points may be considered in initiating research on a new process.

1. The simple decomposition products of the material to be synthesised are determined, and the conditions for the performance of

the back reaction are deduced from the Nernst Heat Equation or from Free Energy Equations.

2. It is sometimes useful to work back from a given product to suitable starting materials.

3. Methods for the synthesis of related compounds should be examined.

4. The possibility of synthesising a derivative which is readily converted to the desired product should be considered.

5. If possible a synthesis should be arranged so that the reactants have a higher energy content than the products.

6. It is sometimes possible by a suitable variation of reagents to form a product under more favourable conditions as regards the equilibria and energy transfers involved.

7. In a synthesis involving several stages it is sometimes advantageous to combine two or more.

8. It is sometimes possible to vary the phase in which a reaction is carried out.

9. The possibility of making a batch process continuous should be considered.

10. As far as possible modern theories of atomic and molecular structure should be applied to the reactions under consideration.

These points may now be considered in detail.

1. The simple decomposition products of the material to be synthesised are determined, and the conditions for the performance of the back reaction are deduced from the Nernst Equation or from Free Energy Considerations.

As an example it is known that acetic acid on pyrolysis yields among other products methane and carbon dioxide,

$$CH_3COOH = CH_4 + CO_2$$

The possibility of synthesising acetic acid from methane and carbon dioxide might be considered. However, application of the Nernst Heat Theorem shows that the equilibrium is unfavourable to the synthesis.

This method of working is of importance in finding a catalyst for a synthesis since a material which promotes decomposition, will also under suitable conditions favour the synthetic reaction.

2. It is sometimes useful to work back from a given product to suitable starting materials.

This point is best made clear by means of a purely illustrative example. We assume that no suitable process for sodium carbonate is known and that one is required. It is taken that sodium chloride is the most readily available source of sodium. It will be expensive to have sodium hydroxide as an intermediate in the process since it is a high energy body compared with a sodium salt; instead, we shall probably as a final stage treat a carbonate of a base with a sodium salt to give sodium carbonate and a salt which separates from the sphere of reaction, so that the formation of sodium carbonate goes to completion. We assume calcium as the base owing to the cheapness and availability of limestone. If it is decided to work in aqueous solution then an acid is required of which the sodium salt reacts with calcium carbonate in aqueous suspension to give sodium carbonate and an insoluble calcium salt. Calcium sulphide is highly insoluble, so sodium sulphide is tried and if the tests are successful, the problem resolves itself into converting sodium chloride to sodium sulphide and so on.

3. *Methods for the synthesis of related compounds should be examined.*

Assuming that a synthesis of acetic acid is required it is known that formic acid can be produced from carbon monoxide and sodium hydroxide, whence acetic acid should be obtained from sodium methoxide and CO. Economic considerations would rule out this synthesis.

Under this heading we may consider the method of generalising a given reaction. Thus the water-gas reaction

$CO+H_2O=CO_2+H_2$ may be written more generally.

$CO+ROH=CO_2+RH$, whence it can at once be seen that CO may produce hydrocarbons from the corresponding alcohols or phenols.

If R equals Na we would expect

$CO+NaOH=CO_2+NaH$, but here the products combine to form $HCOONa$. Again we may write

$$CO+ROR=CO_2+2R$$

which indicates the possibility of synthesising hydrocarbons from ethers.

The use of CO as a reducing agent and of CO_2 as an oxidising agent might provide a profitable line of research. By analogy similar considerations apply to SO_2 and SO_3 and NO and NO_2.

As another instance of generalising a reaction we may consider

$$C_2H_2+H_2O=CH_3CHO.$$

When CH_3OH is used in place of H_2O the corresponding acetal $CH_3CH(OCH_3)_2$ is obtained; the compound $CH_3CH(OH)_2$ is unstable and gives CH_3CHO and H_2O.

4. '*The possibility of synthesising a derivative which is readily converted to the desired product should be considered.*

Thus acetyl chloride might be considered as a possible intermediate in the synthesis of acetic acid; it is known that acid chlorides of the aromatic series are readily obtained by application of the Friedel-Crafts reaction so that a synthesis of acetyl chloride from methane and phosgene is indicated.

If the product possesses any special characteristics which make it difficult to isolate under the conditions of the process, the formation of stable derivates *in situ* should be examined. Thus formaldehyde is very unstable under conditions suitable for the oxidation of hydrocarbons, and it has been suggested that hexamethylenetetramine should be prepared directly by carrying out the oxidation in presence of ammonia and hydrolysing the product. Numerous other examples are provided by the methods employed to protect various groups in the application of organic chemical reactions.

5. *If possible a synthesis should be arranged so that the reactants have a higher energy content than the products.*

It is easier on the whole to control a vigorous reaction than to force a sluggish reaction, and the utility of acetylene as a raw material for organic syntheses illustrates this point. A difficulty may arise in that high energy bodies are usually expensive, on the other hand syntheses in which large quantities of energy have to be supplied usually require high temperatures.

This principle requires qualification, however, while an energy gradient through a process may be desirable it should not be too steep. It may therefore be advisable to perform exothermic reactions in steps in each of which a portion of the energy involved is removed. The practice of nitrating aromatic hydrocarbons in two stages may be cited.

Reactive elements such as chlorine, oxygen and sulphur are of importance when dealing with low energy substances; the chemistry of sulphur is attractive owing to the variety of compounds which it will form.

In this connection when consideration is being given to the use of substances which tend to be waste products in chemical industry and which are usually low energy bodies, *e. g*, calcium chloride or hydrogen chloride, the possibility of reaction with high energy substances should be examined.

6. *It is sometimes possible by a suitable variation of reagents to form a product under more favourable conditions as regards the equilibria and energy transfers involved.*

Thus, if it is sought to obtain a substance with a high energy content such as acetylene, it is advisable to attempt to form simultaneously a substance with a low energy content.

For example the reaction

$$2CH_4 = C_2H_2 + 3H_2 - 90{,}000 \text{ cals.}$$

is difficult to carry out owing to the great excess of energy in the products. But if chlorine is added to the left hand side of the equation we might have

$$2CH_4 + 3Cl_2 = C_2H_2 + 6HCl + 40{,}000 \text{ cals.},$$

and the excess of energy is on the left hand side.

This example is purely illustrative.

A good example of "energy-balancing" is given by a recent patent in which the production of acetone from a mixture of steam, alcohol and acetylene is claimed. The reaction between steam and alcohol to give acetone is strongly endothermic, while that between steam and acetylene is exothermic, so that it is possible by using a suitably proportioned mixture of acetylene and alcohol to obtain exothermic reaction without danger of overheating.

7. *In a synthesis involving several stages it is sometimes advantageous to combine two or more.*

This must be applied with due regard to what is stated in 5. As an example it was found possible to form esters from nitriles directly, thus:—

$$H_2O + CH_3CN + C_2H_5OH + HCl = CH_3COOC_2H_5 + NH_4Cl$$

Previously it had been necessary to isolate the acid first formed from the nitrile, and then carry out the esterification separately.

Again it was known that acetaldehyde and steam give acetone, and that acetylene can be hydrolysed to acetaldehyde; from this a process for the production of acetone from acetylene and steam was developed, the steep energy gradient involved being avoided as described in 6.

Another interesting example is given by the synthesis of ethyl-acetate from alcohol. It was known that ethyl acetate could be obtained by the condensation of acetaldehyde, and that acetaldehyde was readily obtained from ethyl alcohol, so that there was a possibility of passing directly from ethyl alcohol to ethyl acetate. The problem was solved by Du Pont's, who, working in another connection found that ethyl alcohol when heated under high pressure in contact with certain catalysts gave ethyl acetate.

Problems of this type which still wait satisfactory solutions are the direct production of acetic acid from acetylene or ethyl alcohol without intermediate formation of acetaldehyde.

8. *It is sometimes possible to vary the phase in which a reaction is carried out.*

The hydration of acetylene in the gaseous in place of the liquid phase presents an unsolved problem. Reactions such as the chlorination of methane, which up to the present have been investigated chiefly in the gaseous phase might give interesting results if induced in presence of an inert liquid, for example a fully chlorinated hydrocarbon.

9. *The possibility of making a batch process continuous should be considered.*

Originally acetone was manufactured by heating calcium acetate so as to obtain calcium carbonate and acetone. This was made a continuous process by passing acetic acid over calcium carbonate. Again it has been known for some time that ethyl alcohol heated with sodium hydroxide gives sodium acetate. Attempts were made to synthesise acetone by passing alcohol and steam over calcium oxide it being expected that the calcium acetate intermediately produced would give acetone. This occurred but the reaction rapidly came to a standstill owing to the stability of the calcium carbonate formed. In order to make the process continuous it was necessary to find an oxide of which the acetate on heating gave good yields of acetone, and the carbonate decomposed to the oxide at low temperature. A study of the literature showed that zinc oxide possessed these properties and it was found to give good results.

10. *As far as possible modern theories of atomic and molecular structure should be applied to the reactions under consideration.*

This in the present stage of knowledge is not often possible but reference may be made to Sidgwick's book on Valency as an example of how far chemical behaviour can be co-ordinated with the structure of the various atoms. These theories are of greater use in foretelling the properties of crystals and alloys.

The object of this article will have been achieved if some research students are led to believe that chemical research, especially applied chemical research, is a game not entirely without rules.

CHEMICAL TECHNOLOGY

By

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PART I.—THE NEED OF CHEMICAL TECHNOLOGY IN BOMBAY PRESIDENCY

It is literally and metaphorically true that wherever smoke is seen arising from a chimney that is an indication that it is a place abounding in scores of problems to be solved. It is literally true, for a dense black smoke emerging from a tall factory chimney, which is not an uncommon sight in Bombay and particularly in Ahmedabad, shows that there is incomplete combustion of coal in the boilers. This means that more coal is being used than is necessary. In other words the factories spend or rather waste more on their fuel bills which they could easily avoid by the employment of a well trained chemist and technologist who knows how to control not only the process of combustion but also many other processes going on in the factory.

The following example will make clear how necessary it is to employ a trained chemist in a works. The manager of a certain glass factory was a man of long experience but not trained in the principles of science. He once got a big order for red glass. Now he had never prepared red glass. He thought he would be able to prepare it and so accepted the order. He looked up a book of recipes and used copper oxide to produce the colour he wanted, but what was his surprise when he found that he got green colour instead of red. He threw away the whole lot and once again proceeded with the same ingredients more cautiously, but the result was green glass once more. Being a man of the foreman type he naturally groped in the dark and did not know how to find out the cause of his failure. After a few fruitless attempts in which he wasted tons of raw materials, he at last consulted a chemist who asked him whether he had used cuprous or cupric oxide and whether he had carried on the whole process in a reducing atmosphere. This was too much for the foreman manager to understand, for he did not know that there were two kinds of copper oxides and he had never heard about a 'reducing atmosphere'. The chemist explained to him that cupric oxide produced green colour and cuprous oxide a red colour provided it was not allowed to be oxidised to the cupric condition and further remarked that it was as fatal to the industry to use cupric oxide in place of cuprous oxide when red colour was wanted as it was to the life of a human being to use mercuric chloride (corrosive sublimate) in place of mercurous chloride (calomel) for a purge. This will show the intimate connection between science and industry, and the value of scientific knowledge in the efficient management of an industry.

Germany was the first country in the world to notice the close relationship between science and industry. England followed next, then America and finally Japan. The industries are efficiently managed in these countries because they make use of scientific methods and employ scientifically trained men in their works and factories. The industrialists of our country unfortunately have not yet realised the necessity of utilising science in industry and of employing scientifically trained men in their works; hence we see the anomalous position that we find in our industries. It is not a question of greater supply than demand, but it is one of great need but no demand of the scientifically trained men. This fact shows that in our country industry is in the first stage of its growth. This stage corresponds to the employment of old, antiquated, rule-of-thumb methods in industry and carrying on work with the help of men of the foreman type. So long as there is no competition and so long as there is a great demand for the manufactured goods even these inefficiently managed industries will thrive. In the second stage industrialists combine, ask for protection, pray for bounties and imposition of heavy duties on imports etc.; in that way they may be able to carry on for some years. During these two early stages practically no scientific methods, worth speaking about, are employed in any stage of the manufacture. None of the materials are analysed. The yields are not statisfactory; the quality of the finished goods is poor and not uniform; the cost of production is high. In the third stage the industry seems to be threatened by severe competition; either the concern should be wound up or to save itself it should take the help of science. When that is done, one may say that the industry is no longer drifting but is taken in hand and brought under control for the first time.

The first stage in a scientifically managed industry is the analysis of all materials used in the different stages of manufacture. This alone will help the industry to save thousands of rupees. The knowledge thus gained will help to find out whether the quality and yields are poor, whether the cost of production is high etc. Researches should then be undertaken to increase the yield, to improve the quality, to lessen the cost of production by the use of other cheaper and suitable materials and by the modification of existing processes or the discovery of new ones. Researches should also be undertaken to utilise the bye-products and waste-products. The products which were once a nuisance and a curse in the hands of ignorant industrialists now become in the hands of trained scientists and technologists a source of great profit and a blessing. The chemists of the present day are verily the alchemists of old for they bring about an alchemical transmutation of waste-products into useful substances.

Now let us attempt to answer honestly the following questions:

Are our industries efficiently managed? Do our industrialists employ in their works men who are scientifically trained? If, barring a few exceptions, the answer is in the negative, then we must further anlalyse the situation in which we find our industries to-day by putting a few more pertinent questions such as: Is there no need for the employment of scientifically trained men in our Works? Are there no materials to be analysed? Are there no processes to be looked after and controlled? Are there no problems to be solved? Is the combustion of coal in the boilers carried on efficiently? Are the waters analysed to find out whether they are suitable for use in the boilers? Is there no possibility of improving the quality of the products made or of making them cheaper? Are there no by-products and waste products? Could not they be made use of and changed into useful substances?

The moment one enters a factory one notices that there are scores of problems awaiting solution, and that there is room—ample room—for the employment of our University graduates. All of them could be easily absorbed in the different industries. There is an urgent need for employment, in the works, of men trained in science and technology, but, there is no demand for them. Our B.Sc.'s, M.Sc.'s, and even Ph.D.'s have to knock from door to door and find that the doors of factories are closed against them. Our industrialists have no faith in science; they do not understand the value of science to industry; they do not know that discoveries in science and growth in industry go hand in hand in those countries where there is a keen appreciation and encouragement of science and scientific research and an equally keen desire to utilise science in industries.

The facts mentioned above show that the industrialists of our country, with a few honourable exceptions, are lagging very far behind those of other industrially developed countries and that even if the department of chemical technology comes into existence to-morrow there is no guarantee that our graduates in technology will be absorbed in industries and so it is absolutely necessary that the public in general and the industrialists in particular are *educated* by lectures illustrated with slides and cinema films, by opening museums and by practical demonstrations and by showing them what the other countries are doing in this direction. As it may take some time to start the

Department of Chemical Technology the intervening period may best be utilised by carrying on an extensive and vigorous propaganda and with that object in view a committee should be appointed to frame a workable scheme.

PART II.—THE PROPOSED DEPARTMENT OF TECHNOLOGY IN THE UNIVERSITY

The ultimate goal of a University Department of Chemical Technology should be to make the country industrially prosperous. The prosperity of an industry and particularly a chemical industry depends upon its efficient management which, in its turn, depends upon the employment in it of two types of men, *viz.*:

(1) Those who organise and develop industries:
  (*a*) Chemical Engineers, (*b*) Industrial Research Chemists;
(2) Those who operate industries:
  (*a*) the process manager; (*b*) the shift chemists; (*c*) the process workers etc.

If there is any question which is engaging the serious attention of the University at present it is the question of Technology, and it is rightly so. Special impetus was given to this subject by its inclusion in the preamble of the new University Act of 1928. In March 1930 the Academic Council appointed a committee of eleven members, representing Science, Engineering and Industry with Sir M. Visvesvaraya, Kt. as the chairman to draw up a detailed scheme for a University Department of Chemical Technology. After several meetings the committee drew up an unanimous report which was signed on the 31st December 1930, and submitted to the University. According to the report the capital expenditure required for starting a department of Chemical Technology was Rs. 6½ lakhs and the yearly recurring expenditure for running the department was estimated at Rs. 1·25 lakhs. The scheme was originally approved by the Academic Council on the understanding that two legacies which would yield Rs. 8 lakhs and Rs. 2 lakhs were about to be paid to the University. These have unfortunately not become available yet; there is again a further uncertainty as to whether the sum of Rs. 2 lakhs will be paid to the University and there is likely to be some delay in payment to the University of the amount of the first legacy of Rs. 8 lakhs. Again, the University is not in such a strong position financially that it can start the department from its own funds and also maintain it from year to year. Though the University cannot help the Technology scheme at present it has decided that it should take precedence over all other schemes and with that object in view has opened a separate account under the heading of "The Department of Technology" in which will be placed the savings from the working of the University, from the annual income from investments and surplus of the Government grant and which will form a nucleus of a fund which we hope will steadily grow. It is necessary to give a very wide publicity to the Technology scheme and to the fund earmarked for that purpose and a small influential committee should be appointed which should be empowered to take definite steps to collect funds for the purpose in view.

As it is unlikely that a sum of Rs. 6½ lakhs required for the capital expenditure and an endowment fund big enough to give as interest Rs. 1·25 lakhs every year will be collected for some years to come owing to the exceptionally bad times through which we are passing at present, another alternative scheme[1] proposing to train science graduates in Technology is under consideration which will involve a capital expenditure of only Rs. 3½ lakhs and a recurring expenditure of Rs. 55,000.

Under this alternative scheme the course will occupy two years. In the first year all students will study those subjects which are fundamental in all branches of Chemical Technology, *viz.*, German, Mathematics, Descriptive Engineering, Electro-technology, Engineering Drawing, Elementary Chemical Engineering, Construction of Works, Economics, Industrial Chemistry, Fuels, Oils and Fats, Colloids and Dyes, and Intermediates. These studies form the basis on which the student will build when he begins to specialise. Provision will be made for some special training in the first year, but it is in the second year that complete specialisation will take place, the student having the option of two elective subjects—Chemical Engineering and Textile Chemistry. Later on a third elective subject *viz.* Industrial Chemistry will be added if funds permit.

Manchester, one of the biggest industrial centres in the world and the second city in the United Kingdom is not on the sea-coast but on a higher level and inland, about 35 to 40 miles from Liverpool. The industrial magnates of Manchester who had the ambition of trading with the whole world thought that it was most essential that there should be an outlet to the sea for their manufactured goods. How could that be done? Either the sea should come to Manchester or Manchester should go to the sea. After having once fixed their goal they decided within a few days that their city must be linked up with the sea by a canal and with that object in view devised the Manchester Ship Canal project, raised millions of pounds required for this great project in a short time and put it at once into execution. This is real enterprise.

Ahmedabad is often spoken of as the Manchester of India and

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[1] It is a matter of gratification to note that a sum of Rs. 5 Lakhs was sanctioned by the Senate at its meeting held on 17th August 1932 for the *alternative scheme*.

Bombay as the Urbs Prima in Indis. Between them they have more than 200 textile mills; over and above these there are 1,200 factories and works in the Bombay Presidency; they are all in need of men trained in science and technology. There are again as big industrial magnates in Bombay and Ahmedabad as there are in Manchester. The industrialists usually think in rupees, annas and pies, naturally. If they will take a long and far-sighted view they will find that it is to their benefit to have a Department of Chemical Technology in their midst. A sum of six to seven lakhs of rupees which is all that is required for the realisation of the *main* scheme, is a mere flea-bite to some of the millionaires of our Presidency. If our captains of industries *will* to raise this sum they can do so in a *week*. Will they rise to the occasion and do what the Manchester magnates did for their city?

INDIGENOUS DRUGS

By

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I

(1) I became interested in the question of indigenous drugs, and was greatly impressed with the marvellous effects of some of them, from the day, nearly 34 years ago, when one of my intimate friends who was suffering from phthisis and who was given up as hopeless by the best medical men, Doctors of Medicine of the London and Bombay Universities of that generation, was completely cured by a native Vaid by the administration of a few drugs within three months. The friend above referred to was then a young man of 22 years; he is still living, is the father of five healthy children and is holding a high post in a big limited concern.

(2) Dr. John Lindley, an eminent botanist, narrates the following case in the preface to his work on *Flora Medica*. "It is not much above 20 years since an English officer in India was cured of gonorrhoea by his native servant, after the skill of regular European practitioners had been exhausted. The remedy employed was Cubebs, the importance of which was previously unknown and the rationale of whose action is to this day beyond the discovery of physiologists. It is of undoubted value in urethral catarrh and who shall say that there are not hundreds of equally powerful remedies still remaining to be discovered? . . . . and it must be sufficiently apparent to all unprejudiced minds, that the resources of the vegetable kingdom, far from being exhausted, have hardly yet been called into existence."

(3) William Ewart Gladstone, in a speech which he made on the occasion of the opening of Guy's Hospital Residential College, while referring to the importance of the study of Botany, spoke on the great need of observing "all the qualities of plants which are so remarkable and powerful in their healing capacities". In the course of his speech he narrated an anecdote from his own life of how the leaves of a plant healed in half as much time as nature would have taken to do, a cut on his finger which was caused by an axe in wood-cutting.

(4) Writing on the importance of Trees in Medicine, Dr. John Foote, Associate Professor of Materia Medica and Therapeutics states:—

> " And yet, in spite of the pharmaceutical image-breakers and the therapeutic nihilists, some of the most valuable remedies used in medicine come from trees. . . . .
>
> " And if, as has been asserted, the decadence of Rome was really due to malaria, and if her glory was obscured by a cloud of mosquitoes rather than by the dust of battles, then it may be that the possession of some cinchona and the planting of the eucalyptus in the Roman marshes might have prevented a great civilization from withering and fluttering away and changed the countenance of history." (*Scientific American Supplement*, January 13, 1917 p. 26)

(5) A man who was passing 40 stools every day with blood and mucus was brought as an in-patient to one of the hospitals in Calcutta; the I. M. S. officers there who were making experiments, (under instructions of the Indigenous Drugs Committee appointed by the Government of India in 1886,) to test the *reputed* therapeutic value of indigenous drugs, gave him a decoction of *indra jav* seeds. The result of this treatment was that the number of stools came down to 10 the next day; on the third day the number was further reduced to 4 and blood and mucus disappeared and on the fourth day he was discharged from the hospital as completely recovered. The botanical name of this drug is Holorrhoena Anti-dysenterica. One may therefore say that the reputation which *indra jav* enjoyed as an anti-dysenteric drug was well founded. It was this which led me to investigate the *indra jav* drug. The results of this investigation will be given further on.

(6) Last but not the least important drug which I would mention is the drug that cures leprosy. It was known 3000 years ago in India and has been used for the last 200 years in cases of leprosy. It is chaulmoogra oil, the active principle of which is the acid. Its sodium salt mixed with some suitable preparation for injection is called " Alepol " and the most extraordinary thing about it is that, for just a fraction under fifty cents, a leper can be treated for a whole lifetime. Considering the number of lepers in our country which goes to hundreds of thousands at a time (which is larger than that of any other country in the world) and their state of poverty, this means a great thing. This noble work was done by Col. Sir Leonard Rogers, (F.R.S., M.D.,) for it was he who brought the chaulmoogra oil into prominence as a cure for leprosy and who, along with other medical men, found out the proper technique of using it. All honour to him and his collaborators and no less to his wife but for whose inspiration he would not have dared to attempt the cure of a disease that had baffled doctors through all the ages, the dread disease which was a living death to hundreds of thousands.

The few instances quoted above are given with a view to show the importance of the study of the medicinal plants of our country; the need for their systematic and scientific study and investigation cannot be too greatly emphasised.

In a country so vast and so varied in climatic and other conditions as India it is natural that there should be innumerable herbs, plants and trees with medicinal properties; this has been recognized by a large number of European experts who have studied the flora of this country. Lieutenant-Colonel Sir Leonard Rogers, the founder of the Calcutta Tropical School of Medicine, is reported to have said before the Indian Industry Commission, that "most of the drugs imported into India were absolute refuse, and considering that one half of the drugs in the British Pharmacopoeia are indigenous to India and that most of the rest could be cultivated there is clearly an opportunity of developing an industry that has been almost neglected, and if India is to grow its own drugs it must take care that it gets them unadulterated".

Bombay is the greatest store-house in the east for drugs. The condition in which drugs are found in the Indian markets is very unsatisfactory; in many cases the so-called drugs are mere trash; they are of all degrees of staleness; they are usually stored in bags and earthen vessels, they are never labelled and a large number is adulterated.

Taking into consideration all these facts and further that the majority of the people of this country are too poor to buy costly medicines and that they prefer indigenous medicines which they get very cheap it is high time that the question of supplying cheap, reliable medicines obtained from indigenous drugs is taken up in right earnest.

The three questions, of supplying pure medicines of proper standard and at moderate prices, of research on indigenous drugs, and of the manufacture of drugs of proved therapeutic value, are so intimately connected that they should all be considered together.

II

The following sketch will give one an idea of the enormous amount of work that is required to be done before even a single drug is placed on the market. It will also show that for the scientific investigation of the medicinal plants and the systematic development of the drug industry the co-operation and co-ordination of a number of departments is necessary:—

(1) There is a big trade in jungle products going on in our country. There are professional herbalists who are known by different names in different provinces: The Chadras, Bhils, and Gamatas in

Bombay, the Musheras in Central and Upper India and the Malis, Bagdis, Kaibartas, Pods, Chandals, Kaoras and Karangas in Bengal are the herbalists who collect and sell medicine roots and herbs.

(2) These drugs are sold under the vernacular names. Too much weight cannot however be placed on these names.

(3) These drugs must therefore be critically examined by a botanist, identified and classified, for which illustrations of plants are of very great help. This important work of classifying the plants according to species and genera, giving their vernacular, Sanskrit and Latin names, their habitat and uses and their drawings has been done by several eminent men. Their service to the country has been very great and they have deservedly earned the gratitude and blessings of millions of this country. But much more yet remains to be done.

(4) The choice of the drug for the chemical investigation with a view to the isolation of the active principles from the same should be determined by—

- (*a*) the use to which it was put
  - (i) by the Hindu physicians in ancient times (for which the medical works of Charaka, Sushruta, Nighanta etc. should be consulted);
  - (ii) by the Greco-Arabian School of practitioners—the Unani Hakims (for which *Taleef Sheriff* should be consulted);
- (*b*) the reports on its efficiency by the present day practitioners;
- (*c*) the reputation in which it is held by the people to whom it is given;
- (*d*) the reports of Indigenous Drugs Committees regarding its therapeutic properties;
- (*e*) the information gathered regarding the medicinal virtues of a drug from the rustics and villagers who use them. That is how Col. Sir Leonard Rogers came to know about Chaulmoogra oil as a cure for leprosy.

(5) The chemical examination and the presence or absence of the physiologically active principles from the drugs will help to weed out the worthless and bring into prominence the genuine ones.

(6) This will bring about a great improvement in pharmacy, as by this method the pharmacists will be able to give the doctors a medicine of a uniform quality, whose dose could be controlled, unlike the crude drug which varies in its constitution, in the concentration of its active principle and in its physiological characteristics from time to time depending on climate, season, amount of sunshine, nature of soil etc. Again, it will be easy to administer, and being easily assimi-

lable and capable of ready solubility will be more rapid and certain in its action.

(7) After the active principles are obtained in a pure and homogeneous condition showing definite physical and chemical properties the next step would be to send them to a pharmacologist and have their physiological action studied by experiments on animals. The same kind of experiments may be done on plants. (An apparently dead plant was brought to life by the action of a newly-discovered heart stimulant. Sir J. C. Bose's lecture with experiments, before the All India Medical Conference at the Bose Institute, Calcutta, 1930). If the results are encouraging and favourable then they may be clinically tested on the in-door patients in hospitals, who are kept under observation for that purpose.

(8) If the drug passes successfully through the experiments mentioned above and is found to be a most effective medicine then the following procedure should be systematically followed:—

(*a*) Determination of the constitution of the drug and attempts to synthesise it should be undertaken.

(*b*) Researches should also be undertaken on the correlation between the therapeutic values of natural and synthetic drugs and their chemical constitution.

(*c*) If the synthesis of the drug is found to be most difficult and also costly then attempts must be made to grow it on rational lines on extensive farms for we cannot depend for a regular supply of raw materials on the wild grown jungle and forest drugs. The medicinal plants and herbs grown on these farms should then be stored in special depots established for the purpose.

(*d*) These should then be properly identified, classified and labelled.

(*e*) They should then be tested both chemically, pharmacologically and clinically.

(*f*) Researches should also be undertaken to see if the yields of the active principles could not be increased by improvement in cultivation, *e. g.* by the use of selected seeds, by the scientific use of manures etc.

(*g*) Next, chemical researches should be undertaken on the plants and herbs grown on the medicinal farms. For this purpose they must be collected at different times of the day and in different seasons of the year. The chemical investigations will show if there is any change in the quality or yield of the active principles on account of these variations.

(*h*) At the same time researches should be undertaken to see if these active principles, isolated in small quantities in the laboratory could be cheaply manufactured on a commercial scale, the objects to be kept in view being (i) pure quality, (ii) high yield, (iii) low cost of production.

(9) If the medicinal plant is indigenous to our country, then by the employment of scientific methods in cultivation on large and extensive tracts of land, immense quantities of the crude drug could be obtained which would yield sufficient quantities of the active principles to supply the whole world. This may be done not only in the case of one medicinal plant but hundreds. In this way a large industry in indigenous drugs would grow up in our country which would bring in millions of rupees and give employment to thousands of people. It would be worth while to quote here Prof. Greenish, Dean of the School of Pharmacy, London, who stated in an interview that " in his opinion India owing to the remarkable variations she possesses in respect of climate, altitude and soil, is in a position to produce successfully every variety of medicinal herb required by the Empire".

(10) India is the home of pharmacy. Countless medicinal plants could be cultivated on our soil on scientific lines, and valuable medicines manufactured from them ; to mention only a few, quinine from cinchona, morphine from the Indian opium poppy, santonin from Artemisia Brevifolia which grows wild and in abundance in Kashmir, podophyllum for liver complaints from Podophyllum Emodi, (a tree which grows in Kashmir and which contains twice as much resin as the American variety Podophyllum Palatum and is therapeutically more active. The commercial value of both these last mentioned drugs is nil at present for lack of enterprise), strychnine from nux vomica, thymol from Ajwan seeds, ginger, castor oil seeds, valerian roots, cannabis Indica (Indian hemp) etc. etc.

(11) India imports drugs and medicines of the total value of more than two crores of rupees [Rs. 2,02,12,960 (1928-29) Report of the Committee on the Scheme for a University Department of Chemical Technology, 1930]. These statistics and the facts mentioned above show that there is a vast field for the development of a drug industry in our country.

(12) It will also be seen that the drug industry, if it is to be successful, necessitates the co-operation and co-ordination of the agriculturist and the horticulturist, the economic botanist, the chemist with special knowledge of the highly technical subject of chemistry of alkaloids etc., the pharmacologist, and the medical man.

(13) The drug industry again affords a wide scope for *research* in many different branches of science like agriculture, horticulture,

botany, chemistry, pharmacology etc. This being the case there should not be a single University in the whole of India which has not 'indigenous drugs' as a subject for research. The field for research in these different directions and from different points of view is inexhaustible; the harvest is rich but the labourers are few. Research is described by a great scientist as the honey of modern civilization. It makes life sweeter and more enjoyable. The research scientists are the busy bees who gather the honey from the flowers in the gardens and fields. Research is the process of honey making and honey gathering. We want more honey gatherers, we want more busy bees, and the University should see that the honey gatherers and busy bees get every possible encouragement and facility in their arduous work.

(14) In the Appendix is given a table showing researches done on indigenous drugs during the last few years. A glance at the table will show how little work has been done on drugs in our country and particularly in our University. This will be an eye-opener to many of us. Those who are interested and engaged in the study and investigation of indigenous drugs in our Presidency could be counted on one's finger-tips.

(15) Among the steps which may be taken by the University, the Government, and the public to remedy this state of affairs, the following may be mentioned:—

(A) The Institution of a Degree in Pharmaceutical Chemistry. The appointment of the Drugs Enquiry Committee by the Government of India was a step in the right direction. The recommendations of the committee are:—

- (*a*) Legislation to control Drugs and Pharmacy.
- (*b*) Central and Provincial laboratories to test drugs and do research work.
- (*c*) The General Council of Pharmacy.
- (*d*) The Institution of a Degree of Pharmaceutical Chemistry.
- (*e*) The Cultivation of Medicinal Plants and Herbs.

These recommendations when carried out will no doubt give a great impetus to the Indigenous Drug Industry.

It is a matter of satisfaction to us to note that one of our ablest men and an unassuming solid worker, the Rev. Father Caius of St. Xavier's College, Director of the Pharmacological Department, Haffkine Institute, Bombay, had the honour to serve on this Committee.

Bombay being the home of pharmacy and the biggest store-house for drugs in the east, the Bombay University should take early steps to institute the Degree of Pharmaceutical Chemistry.

(B) Establishment of Research Scholarships for indigenous drugs.

(C) Co-operation between researchers on indigenous drugs.

(D) Co-ordination between the existing Government Departments such as those of:
  - (*a*) the Directors of Agriculture and Horticulture,
  - (*b*) the Economic Botanist,
  - (*c*) the Analytical Chemist,
  - (*d*) the Pharmacologist etc.

(E) Co-operation between the Central and Provincial Laboratories as recommended by the Drugs Enquiry Committee or some other such agency or Works on the one hand and the Researchers on Drugs in the Colleges on the other in the matter of undertaking by the former on behalf and under instructions of the latter, the large scale preliminary operations of getting the drug, grinding it and then extracting the same with organic solvents.* This would save a lot of time and energy which would be usefully spent in doing research on the extract supplied and thus considerably accelerate the progress of the work.

This is the most practical suggestion I am making in this article. This suggestion is the outcome of my personal experience for I know how ill-equipped even large college laboratories are for this type of work and the difficulties and handicaps under which a researcher on indigenous drugs has to work—difficulties and handicaps which would severely try one's enthusiasm for work of this kind. I, therefore, commend this suggestion for the very careful consideration of the Government, the University and no less of our leading citizens, capitalists and industrialists who are keen on the scientific investigation of medicinal plants and a systematic development of the drug industry.

(F) The formation of an Association of Pharmacists and Dealers in Drugs.

(G) The institution of a Diploma in Pharmaceutical chemistry.†

(H) The foundation of a Chair in Pharmaceutical Chemistry at the University.

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* The physiologically active principles like alkaloids etc. are usually present in the drug to the extent of half or one per cent or so, hence the necessity of working with large quantities of the drug for which there are no adequate facilities in the college laboratories. In the large-scale operations one works with pounds and not with grams as in the laboratory.

† The Resolution regarding the Institution of a Diploma in Pharmaceutical Chemistry is before the Senate now.

APPENDIX

1924

Travancore Essential Oil from Ageratum Conyzoides, Linn, (Appa Grass).—By Kishori Lal Moudgill, Trivandrum.

It contains about 90% of a compound, $C_{13}H_{16}O_2$ which is under investigation.

1925

Vasicine—An alkaloid present in Adhatoda Vasica, Nees.—By J. N. Sen and T. P. Ghose, Dehra Dun.

It contains an alkaloid Vasicine, m. p. 190^0–191^0; empirical formula $C_{11}H_{12}N_2O$; some salts of vasicine are described.

Alangium Lamarckii : Alkaloids from the bark of the root of, —By Darab Dinsha Kanga, Ahmedabad.

The drug is reputed to possess medicinal value. There are at least two alkaloids in the drug, one non-phenolic obtained in a pure crystalline form m. p. 170^0 sharp but obtained in very small quantities; the other phenolic may probably be a mixture of two alkaloids; they have not yet been obtained pure; the phenolic is in a greater proportion than the non-phenolic.

Travancore Essential Oils Part IV, from Cymbopagon Caesius ; Staph, (Inchi Grass).—By Kishori Lal Moudgill, Trivandrum.

Borneol is a constituent of the oil from 'inchi' grass. The oil does not undergo any change in keeping. The oil is sweet smelling. It resembles palmrosa oil in odour. The other constituents of the oil are also described.

Karanjin. A crystalline constituent of the oil from Pongamia glabra seed, Part I.—By D. B. Limaye, Poona.

The new compound Karanjin ($C_{18}H_{12}O_4$) has been shown to be the methylether of Karanjonol ($C_{17}H_{10}O_4$), which possesses feeble tinctorial properties. Acetyl and benzoyl derivatives and the ethyl ether of Karanjonol are described.

1926

The Essential Oil from the Flowerheads of Perovskia Atriplicifolia, Benth.—By Madyar Gopal Rao, Dehra Dun.

It consists of *d*-α-pinene, β-pinene and camphene (definitely confirmed), 15·18% of alcohols and esters consisting mainly of *d*-borneol and bornyl acetate, and the rest of sesquiterpenes consisting mainly of α-caryophyllene and aromadendrene. As a source of *d*-borneol this oil would seem to be of interest.

A note on the Variable Tannin Content of the Wood of the Kumaon Oak. (Quercus incana).—By H. S. CHATURVEDI and E. R. WATSON, Cawnpore.

The percentage of tannin in the wood varies in a most capricious manner and considering that the tannin is always on the low side, the wood does not seem worth further consideration as a source of tannin extract.

The Manufacture of Strychnine and Brucine from Nux Vomica.—By E. R. WATSON and H. D. SEN, Cawnpore.

A successful method for the manufacture of strychnine from brucine is described.

Karanjin Part II. Products of alkaline hydrolysis of Karanjin.—By D. B. LIMAYE, Poona.

On hydrolysis Karanjin gives (1) benzoic acid, (2) a phenolic body $C_{11}H_{10}O_4$ m. p. 93^0C., (3) Karanjol carboxylic acid $C_9H_6O_4$ which melts at 200^0 with decomposition and (4) a neutral, sweet smelling liquid with Ketonic properties B. P. about 230^0.

Vidangin. A colourless crystalline constituent of Vidanga berries (Embelia Ribes).—By D. B. LIMAYE and A. B. LIMAYE. Poona.

A colourless constituent m. p. 115^0–116^0 hitherto not isolated from the berries, has been described; on the oxidation it gives orange flakes m. p. 142^0 C.

Conessine.—By D. D. KANGA, P. R. AYYAR and J. L. SIMONSEN, Ahmedabad and Bangalore.

Conessine (alkaloid from the seeds of Holorrhaena antidysenterica, Vern. name Indra Jav) m. p. 125^0. ($C_{24}H_{40}N_2$ empirical formula). It contains two tertiary *Nme* groups. Some derivatives of Conessine are described; apoconessine ($C_{22}H_{33}N$) m. p. $68{\cdot}5^0$, (hydrochloride, hydrobromide, hydrogen sulphate, m. p. $107{\cdot}8^0$, picrate m. p. 110^0–111^0, methiodide, m. p. 283^0–285^0). Dimethosulphate of conessine (m. p. 240^0–242^0) yields a hygroscopic base, $C_{26}H_{44}N_2$ [dipicrate, m. p. 258^0–259^0 (decomp.), and dimethoidide described].

1927

Vasicine. An Alkaloid Present in Adhatoda Vasica, Nees. Part II.—By TARAK PRASAD GHOSE, Dehra Dun.

Empirical formula of Vasicine alkaloid contained in Vasica is $C_{11}H_{12}N_2O$. It is monobasic. Oxidation product with $KMnO_4$ m. p. 213°–214°. Vasicine behaves as a tertiary base.

The Constitution of Rottlerin from Indian Kamala. Part II. —By SIKHIBHUSHAN DUTT and DHANRAJ PURI GOSWAMI, Allahbad.

Molecular formula of Rottlerin is $C_{33}H_{30}O_9$ and it contains four benzene nuclei. Some derivations are described.

Oil from Pinus Gerardiana-Chilgoza Oil. Part I.—By S. D HARDIKAR, Gwalior.

In Ayurvedic medicine, the seeds are considered as an anodyne, stimulant, and are also useful in chronic rheumatic affections. The kernel contains about 50% of the oil. The oil is non-volatile. Nearly 95% of the oil consists of glycerides of unsaturated fatty acids.

1928

Constitution of the Active Principle of Chita. Part I.—By AMARESH CHANDRA ROY and SIKHIBHUSAN DUTT, Allahbad.

It is made use of in various prescriptions for dyspepsia, paralysis, leprosy, plague etc. Its m. p. is 72°, and formula $C_6H_{18}O_6$. In the present investigation the m. p. has been found to be 78° and the molecular formula $C_{18}H_{15}O_5$. It is a neutral substance.

The Alkaloids of Kurchee Bark (Holarrhena Antidysenterica). Part I.—By SUDHAMOY GHOSH and NAGENDRA NATH GHOSH, Calcutta.

The content of alkaloids in the Kurchee Bark is found to be about 1·2%. A new method is described for the separation of the individual alkaloids. Two new alkaloids have been discovered.

Jute Seeds. Corchorus Capsularis. Part II. The composition of Oil Corchorus.—By NIRMAL KUMAR SEN, Dacca.

Some of the Chemical and Physical characteristics of a sample of Jute Seed Oil have been described. It contains the glycerides of oleic and linolic acids. The pure oil is suitable as a food and also satisfactory for burning purposes.

1929

Some Constituents of Caesalpinia Bonducella Nut (Flem). Part I. Bonducella Nut Oil.—By S. N. GODBOLE, D. R. PARANJPE and J. G. SHRIKHANDE, Nagpur.

The percentage of nut oil yield is 60-80. Kernel yield 20%. The glucoside from the oil-extracted kernel contains most of the sulphur of the Bonducella nut. It has a poisoning effect on the nickel catalyst. The acids present are in the form of glycerides of oleic, linoleic, palmitic, and stearic acids.

Chemical Examination of the Roots and Leaves of Saussurea Lappa, Clarke. Part I.—By SUDHAMOY GHOSH, NIHAR RANJAN CHATTERJEE and ASHUTOSH DUTTA, Calcutta.

Essential oil in the root is 1·5%; Alkaloid (Saussurine) 0·05%. Alkaloid in leaves 0·02%. Essential oil has antiseptic and disinfectant properties. It is a diuretic. The drug has controlling effect in the attacks of bronchial asthma.

Constitution of the Active Principle of Embelia Ribes. Part I.—By RAMJEE KAUL, AMARESH CHANDRA RAY and SIKHIBHUSAN DUTT, Allahbad.

It gives a dark coloured aliphatic oil and an orange coloured yellow crystalline substance Embelin, formula $C_{18}H_{28}O_4$. Embelin contains two hydroxyl groups. These groups are capable of Keto-enol tantomerism. Embelin on crystallisation yields long yellow needles m. p. 142^0.

Studies in the Ligno-cellulose Group. Part I. An Investigation into the Constituents of Water Hyacinth (Eichornia Crassipes).—By H. K. SEN, P. P. PAL and S. B. GHOSH, Calcutta.

Percentage composition of the air dried plant cellulose 42·23%; ash 16·75%; lignin 11·31% etc.

The Chemical Examination of thc Oil from the seeds Butea Frondosa, Roxb.—By M. C. TUMMIN KATTI and B. L. MANJUNATH, Bangalore.

The seeds are used in Ayurvedic as an anthelmintic drug. Percentage of the oil in the seed is 18%. Acids isolated from the oil: Unsaturated:—Oleic and linolic. Saturated;—Palmitic and lignoceric acids, fraction of *mol. wt. 354 and 383.*

An attempt to prove the constitution of Embellic Acid.—By K. S. NARGUND and D. D. KANGA, Ahmedabad.

The following new derivatives have been prepared and analysed:

(*a*)	a monoacetyl derivative	m. p. 57°–58°
(*b*)	a monosemicarbazone	m. p. 205°–206°
(*c*)	a disemicarbazone	m. p. 255°–256°
(*d*)	a dihydrazone	m. p. 178°–180°
(*e*)	an oxime	m. p. 178°

1930

Chemical and Physico-chemical Examination of Eupatorium Ayapan and Justicea Gandharussa.—By N. C. NAG and K. BOSE, Calcutta.

Both are medicinal plants with distinctive physiological actions. p_H values of the saps of both are given. A quantitative study of the following constituents was made, both in the ash and in the dry matter obtained from the plants:—moisture, ash SiO_2, P_2O_5, Cl, NO_3, total N, SO_3, Fe, CaO, MgO, Na, K, fibre, sugar convertible carbohydrates etc.

Jute Seeds, Corchorus Capsularis. Part III. Their Chemical Composition.—By NIRMAL KUMAR SEN, Dacca.

Active principle of the seeds. Corchorin ($C_{22}H_{36}O_8$) bitter taste, m. p. 174°–175° and is a glucoside.

Chemical Examination of the seeds of Caesalpinia Bonducella, Flem. Part I.—By M. C. TUMMIN KATTI, Bangalore.

The bitter principle 'Bonducin' indefinite M. P. was administered to malarious patients. Six out of eight cases were reported as successful.

Chemical Examination of the Seeds of Caesalpinia Bonducella. Flem. Part II. Fatty Oil.—By M. C. TUMMIN KATTI and S. V. PUNTAMBEKAR, Bangalore.

The oil has been found to contain the glycerides of some acids *e.g.* palmitic, stearic etc. two phytosterols, one m.p. 122°–123° and the other sitosterol and a hydrocarbon m. p. 58°–59°.

Chemical Examination of Sida Cordifolia, Linn.—By SUDHAMOY GHOSH and ASHUTOSH DUTT, Calcutta.

The hydrochloride of the alkaloid, crystalline both from alcohol and water in colourless needles m. p. 215·5°. Pharmacological action causes marked and persistent rise of blood pressure in anaesthetised or decerebrated animals. The drug contains about 0·085% of alkaloids.

Constitution of Corchorin—the Active Principle of Jute Seeds (Corchorus Capsularis). Part I.—BY NIRMAL KUMAR SEN, Dacca.

Corchorin is a bitter glucoside; composition $C_{22}H_{38}O_8$ gives a pentacetyl derivative, crystalline. Corchogenin ($C_{16}H_{28}O_8$) forms a dibromide on bromination. With Phenylhydrazine a solid m. p. 165°–170°. Corchorin forms with bromine a dibromide m. p. 100°. (decomp.) and on acetylation acetylcorchorin (m. p. 158° with decomposition).

1931

Chemical Examination of the Marking-nut. (Semecarpus Anacardium, Linn).—By P. PARAMESWARAN PILLAY and SALIMUZZAMAN SIDDIQUI, Delhi.

The black corrosive juice of the pericarp of the nut has been found to be of great medicinal value, internally in cases of rheumatism, epilepsy, nervous debility, piles and dyspepsia; externally for eczema, lepra and other skin diseases.

Diacetyl of Hydrobhilawanol m. p. 51°.
Dibenzoyl hydrobhilawanol m. p. 59°–60°.
Mononitrohydrobhilawanol Methyl Ether m. p. 71-72°.
Dinitrohydrobhilawanol Dimethyl Ether m.p. 83°.

Constitution of the Active Principle of Embelia Ribes. Part II.—By RAMJEE KAUL, AMARESH CHANDRA RAY, and SIKHIBHUSHAN DUTT, Allahbad.

It has the formula $C_{18}H_{28}O_4$. Contains two hydroxy groups and two Ketonic groups. In this investigation it has been shown to contain two methylene groups. Action of some acids on Embelin is described.

Constitution of Embelin.—By K. S. NARGUND and B. W. BHIDE, Ahmedabad and Poona.

Presence of two Keto groups is proved in the molecule. Embelin m. p. 143°. Oxidation and Hydrolysis are described.

The Oil from the Seeds of Putranjiva Roxburghii, Wall.—By S. KRISHNA and S. V. PUNTUMBEKAR, Dehra Dun.

The leaves and stones of the fruit are officinal in certain parts of India and are given in decoction in colds and fevers. The seeds yield a pale yellow oil. 42·9% of an oil in the kernel. The oil from the seeds has been found to contain the glycerides of certain acids, together with sitosterol m. p. 143⁰-145⁰.

A Note on the Main Constituents of the dried Rind of the Fruit of Garcinia Gambogia.—By K. I. KURIYAN and KANTILAL C. PANDYA, Agra.

It is found to contain about 10% of tartaric acid.

Composition of Parkia Oil.—By DINKER RAMCHANDRA PARANJPE, Nagpur.

The oil contains 7·9% behenic acid. 39·4% unsaturated linoleic acid.

Chemical Examination of the roots of Rauwolfia Serpentina, Benth.—By SALIMUZZAMAN SIDDIQUI and RAFAT HUSSAIN SIDDIQUI, Delhi.

Roots used as a remedy for snake-bites and dysentery etc. Total alkaloidal yield 0·5%. Five crystalline alkaloids have been isolated:

Ajmaline ($C_{20} H_{26} O_2 N_2$)	M. P. 158⁰–160⁰.
Ajmalinine ($C_{20} H_{23} O_4 N$)	M. P. 180⁰–181⁰.
Ajmalicine	M. P. 250⁰–252⁰.
Serpentine ($C_{21} H_{23} O_4 N$)	M. P. 153⁰–154⁰.
Serpentinine	M. P. 263⁰–265⁰.

Active Principles from Solanum Xanthocarpum.—By D. D. KANGA, Ahmedabad.

Fruits were examined separately as well as the whole plant. Fruits: a gluco-alkaloid is found in the fruits. On hydrolysis it gives a crystalline compound m. p. 174⁰-175⁰, and a sugar. The alkaloid gives an insoluble hydrochloride. Petroleum ether extract gives a crystalline substance m. p. 245⁰ C.

Whole plant: The same gluco-alkaloid is found here also. Alcoholic extract gives a complex substance giving tests for a chloride, a nitrate, potassium, a trace of iron, and more than one organic substance. From the aqueous extract potassium chloride (cubes), and potassium nitrate, (long flat needles) crystallize out.

The Chemical Constituents of Withania Somnifera.—By D. N. MAJMUDAR and P. C. GUHA, Bangalore.

A reducing sugar, phytosterol, ipuranol, mixture of saturated and unsaturated acids and a small quantity of a basic substance supposed to be an alkaloid have been isolated.

MECHANISM OF CHEMICAL REACTIONS

By

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PART I

Considerable importance is attached to the mechanism of chemical reactions in the progress of modern chemistry. A large number of chemical reactions are known to-day, and the mass of information available in connection with the reaction velocity, reacting substances and products is also great; yet when a little thought is given to the mechanism of these reactions we find that only in a few cases the reactions are completely understood. Numerous problems confront chemists in their work. For instance, what happens when a substance passes in solution? What are the processes of evaporation and condensation like? Is sublimation a simple process of only two reactions *e.g.* the vaporisation of a solid and the condensation of the vapour to a solid state, or are there other stages also involved? How is it that the liquid state is not realised in both reactions? What happens when a solid substance melts and a liquid substance solidifies? Are the decompositions of the solid and liquid substances so simple as they are expressed by chemical equations in text-books of chemistry or are there additional stages which are yet to be discovered? The processes outlined above are the common operations which chemists are using for the last many years in the study of chemical reactions, and yet how little do we know of them? Tentative explanations and definitions of these processes, given in text-books of chemistry from the theoretical standpoint, are no doubt satisfactory according to the present state of our knowledge; but there still lies an immense scope for further experimental work to elucidate the mechanism of these processes.

So often, questions have arisen as to how the gaseous, liquid or solid substances burst into flames when they react chemically. Apparently the process is extremely rapid or instantaneous, but are there no stages, involving intermediate compounds, before the final products are obtained? Are explosions simple reactions or are they complicated? The explosion of gunpowder, where finely divided charcoal, sulphur and saltpeter react violently with a loud detonation, is still a mystery to chemists. How do other explosives such as trinitrotoluene, nitroglycerine, etc., detonate and what are the successive stages which lead to final products? The same thing may be said about the process of combustion which organic chemists employ for studying the composition of organic substances. Are these substances directly converted into carbon dioxide and water or are there any intermediate reactions involved in the process? Similar questions are lying unsolved as far as the processes of decomposition and oxidation of organic substances are concerned. During recent years considerable interest has been displayed and useful experimental material obtained in this direction. We have yet to learn how charring of sugar, starch and other organic substances takes place when they are heated. What do we know of the reactions involved in the conversion of sawdust, or of canesugar, into oxalic acid? There are numerous colour reactions which organic chemists are using in their qualitative work and the mechanism of these reactions is yet unknown. Among these might be mentioned the reactions with ferric chloride, sodium hypochlorite, hydrogen peroxide, potassium dichromate and sulphuric acid, etc.

In Inorganic Chemistry too, the problems of similar nature are enormous in number awaiting further experimental work and solution. For instance, how do metals and non-metals react with different acids producing different substances under varying conditions? What changes are produced in metals when they are rendered passive? How do hydrates change their colour at different dilutions? When a large number of free organic radicals are now known, how can inorganic radicals be isolated in the free state? What do we know of catalysis? Traces of impurities of foreign substances are found to exert an enormous influence on chemical reactions and their use in chemical industries is not uncommon. Farrington Daniels (*Chemical Reviews*, 1932, X, 1) writes that " the industrial chemist has learned, empirically, how to obtain the desired result through the control of temperature, concentration and the use of catalysts . . . . . . But he knows little concerning the intermediate steps or the actual mechanism involved. These things must be studied by theoretical chemists who have an intellectual interest in them". H. S. Taylor (*Chemical Reviews*, 1931, IX, 1) expresses similar views: " The application of the term 'catalysis' to a set of chemical phenomena is, in major part, a confession of ignorance. It normally indicates the existence of a series of chemical reactions of which the initial and the final states are readily studied, while, of the path between little or nothing is yet known. When known, the need for the term 'catalysis' disappears, for the total process becomes a succession of normal chemical reactions."

PART II

There are two questions which are often put to chemists: (i) Why does the chemical reaction proceed? (ii) How does the chemical reaction proceed? The first question, namely, the cause of chemical action has puzzled man from the earliest ages and remains unsolved even today. The second question, however, which deals with the mechanism of chemical reaction has been attacked successfully by chemists and there is a possibility of getting a solution for each chemical reaction as the following paragraphs will show.

Alchemists believed that two or more dissimilar substances interact due to the presence of a selective force called 'chemical affinity'. Berzelius expressed the same concept in his electrochemical theory and Newton held similar views. Affinity tables were compiled by Geoffroy (1718) and Bergman (1775). The latter argued that if A displaces B from one compound and B displaces C from another compound the order of these substances is A, B, C. This theory of affinity was called into question by Berthollet (1799) because it was incompatible with the experimental observations. Berthollet showed that "the chemical action is conditioned not only by affinity but by relative concentrations of the reacting bodies" or in other words the activity of a substance is proportional to the product: (affinity) × (concentration) which is termed 'Active Mass'. A weak affinity is strengthened by a large concentration and a strong affinity is weakened by a high dilution, and thus by changing the concentrations of the reacting bodies a chemical reaction can be reversed.

Two such opposite reactions are found to be at work in many examples of chemical action. When the velocities of the direct and reverse reactions tend to be equal, the system is said to attain a state of dynamic equilibrium. Chemical changes of this kind are known as 'balanced' or 'reversible' reactions because one reaction is undoing the work of the other.

Subsequent investigations on the effect of temperature, pressure and change in concentrations of the reacting substances on chemical equilibrium showed that "if a system in equilibrium is subjected to a constraint, a change occurs, if possible, of such a kind that the constraint is partially annulled".

There are many chemical reactions which appear to go to completion, instead of to a state of equilibrium, and are styled as 'irreversible' reactions. This happens due to the disturbance of the equilibrium state when one or more of the products are removed from the sphere of action by their volatility or insolubility. Many of these reactions, apparently irreversible, are not so in reality. If sodium amalgam be allowed to react with water in a thick walled vessel fitted with a manometer, the speed of the reaction gradually slackens with the increasing pressure of hydrogen and finally stops (Caillitet, 1869). With zinc and sulphuric acid this happens when the pressure of hydrogen is nearly 20 atmospheres. It has also been observed that if salts like zinc sulphate, silver sulphate etc., are exposed to hydrogen under pressure over 100 atmospheres, the metal is produced and the acid is reformed (Beketoff, 1864). In the combustion of sugar in air there is no trace of sugar left in equilibrium with carbon dioxide, water and oxygen and the action is irreversible. Nevertheless, the reversible reaction takes place in green plants under the influence of sunlight.

Since chemical equilibrium is dependent on the rates of direct and reverse reactions, it was once thought that the mechanism of chemical action would be elucidated if the velocity of the chemical action were accurately determined. For this purpose a large number of methods have been devised and used: it has been found that a vast majority of reactions either take place so rapidly or are complicated to such an extent that no specific coefficient of velocity for the action can be calculated. On the other hand, there are reactions which are so slow that hours, months and sometimes years are needed to detect any appreciable change. An exhaustive study of these slow reactions, the rates of which are easily measurable, has led to the classification of reactions into two divisions: (i) Isolated Reactions and (ii) Simultaneous Reactions. Isolated reactions are those where a single reaction takes place without any complication of a secondary reaction. Simultaneous reactions are those where in addition to the main reaction, (*a*) the products of the reaction recombine giving 'reversible' reactions, (*b*) the products of the reaction react among themselves or with the reactants to produce new substances giving 'successive' or 'consecutive' reactions, and (*c*) the reactants combine in more than one way giving 'concurrent' or 'side' reactions.

In (i) it is nowadays customary to refer to reactions as unimolecular, bimolecular or trimolecular reactions depending on the number of molecules which take part in the reactions. Reactions of higher order than the third are very rare and usually the velocity constants are far from satisfactory.

In (ii) it is possible to study simple cases of 'balanced' reactions: the net velocity of a reaction is given by the difference in the velocities of direct and reverse reactions. The treatment of consecutive and concurrent reactions, however, is very complicated and experimentally difficult. When we measure the rate of a complicated action we are in general measuring an average rate of a series of reactions which may be progressing successively or simultaneously and it is the rate of the slowest of these reactions which plays the principal part in determining the total rate. This is the main reason why so many reactions, though complex in nature, are found to be, from velocity determinations, comparatively simple.

The whole subject of consecutive and concurrent reactions is in a very unsatisfactory condition and a great deal of uncertainty exists as to the mechanism of reactions proceeding in the main changes. While discussing the mechanism, therefore, it is important to distinguish completely between the chemical equations which chemists use in representing total chemical changes, *i.e.* stoichiometric equations described in text-books of chemistry, and the equations which should represent the actual reactions proceeding in stages. The measurement of the rate of reaction no doubt constitutes a valuable method for finding the mechanism of many simple changes, but in complicated cases the method leads to erroneous conclusions. Under such conditions it is necessary to conduct experiments by using different initial concentrations of the reacting bodies under different conditions and examine the products qualitatively and quantitatively. Moreover, when extremely rapid reactions are found to proceed along with slow reactions, it is necessary to search for new methods of attack to study such rapid reactions at the initial stage.

I believe this will show how difficult it is to investigate a complicated chemical action. The greater the complexity of an action, the greater are the complications to be overcome and the experimenter gets confused in attacking the problem in actual practice. This explains why the investigators have chosen and are choosing simple homogeneous reactions either in the gas phase or in solution: the gas reactions are simpler because they are not complicated by the solvent.

A large number of investigations have shown that even simple reactions on close examination are found not to be so simple. It is now known that

(1) water profoundly modifies the properties of substances with which it is in contact, and

(2) minute traces of impurities or at times the walls of the glass vessel in which the reaction is studied have an enormous influence on the reactions in the gaseous phase.

The representation of chemical changes in such cases by means of chemical equations where elements of water, impurities or glass are absent is apparently incorrect. Such a type of chemical equation conveys no idea of the mechanism: it simply shows the beginning and the end of the reaction. Really speaking, chemists should make an attempt to obtain a completer view of the mechanism of a reaction, 'truth, not simplicity, being the ultimate object of their work'. A. L. Lavoisier has pointed out that " it is a necessary principle in experimental work to eliminate every complication and to make experiments as simple as possible. The quality of an experiment, not the quantity is best adopted to throw light upon a phenomenon. The more intricate the experiment, the greater the probability of an obscure and ambiguous result. Experiments carelessly performed become sources of error and obscurity."

The chemical kinetics pertaining to heterogeneous systems present problems of still greater complexity, although they have wider technical applications. The processes which chemists employ either in a laboratory or in a factory, namely, evaporation, condensation, crystallisation, sublimation, decomposition of solids, catalysis etc., belong to this class. They are also of vital importance in natural phenomena. In these systems, the reactions usually proceed in gaseous, liquid or solid state at the surface of solids or in liquids. Our knowledge in this direction is superficial at present, because we know very little about (*a*) the molecular state, and (*b*) the exact nature of the surface, of liquids and solids. In connection with the former, Professor H. B. Baker pointed out in his Presidential address delivered before the Chemical Society, London, on 24th March 1927 that the molecular constitution of liquids is complex due to the association of molecules. In regard to the latter, no definite information is yet available, although the research of the past 15 years is highly suggestive and shows prospects of solution in future. The main contributions in this field are from Langmuir (*Jour. Amer. Chem. Soc.*, 1915: *37*, 1154; 1918: *40*, 1361; 1932: *54*, 2798) and Keyes and Marshall (*ibid.*, 1927, *49*, 156). This shows that complexities and experimental difficulties attending the investigations of heterogeneous reactions are enormous. The experimental work so far available in this field is not much and the accumulation of such material is one of the tasks of the future.

RESEARCHES IN COLLOIDAL CHEMISTRY IN INDIA

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It is well known that the term colloid was first assigned to substances which diffused very slowly through a parchment paper. Now it is recognised that colloidality is not the property of a single substance but of a system in which one substance is dispersed into another. These systems are called disperse systems and theoretically it is possible to obtain nine such systems depending upon the state of aggregation of the disperse phase and the dispersion medium. Most of the common substances, such as milk, butter, blood, fruit jellies etc. belong to the disperse systems known as sols, emulsions and gels and because of their technical importance these have been most extensively studied.

(A)—SOLS

(*i*) *The Electric Charge on Colloidal Particles.*

Colloidal systems in which a solid is dispersed in a liquid are known as sols. The particles of the disperse phase carry an electric charge, either positive or negative, the origin of which has been attributed to (i) the friction between the disperse phase and the dispersion medium and (ii) the adsorption of the ions of electrolytes during their formation.

Dr. J. N. Mukherjee who was the first to initiate research work in colloidal chemistry in India, has supported the latter view of the origin of charge on particles in a sol and has shown that the charge on a colloidal particle is of the same sign as that of the ion which is common to the substance of the particle and the stabilising electrolyte. According to Dr. Mukherjee the adsorption of ions by the particles during their formation is determined by the chemical forces which act in the same way as in the growth of a crystal in its solution. Some of the oppositely charged ions of the electrolytes for which W is greater than $n_1n_2E^2/Dx$ are also held bound to the chemically adsorbed ions and decrease the density of the charge on the particles. The remaining ones (there being as many oppositely charged ions as those chemically adsorbed) are free and form a second sheet or a "double layer" round the particles, the thickness of the double layer being of the order of molecular diameters.

In a paper published in the Proceedings of the Royal Society Dr. Mukherjee has shown that the simple U-tube method of measuring the electric charge on colloidal particles employed by Burton and other workers involves errors which are due to (i) the electrolysis at the electrodes and the diffusion of the products of electrolysis and (ii) the migration of ions across the boundary. He has modified the method by introducing four tubes, bent at right-angles, one centimeter apart from each other, in one of the arms of a U-tube and has shown that the changes in the resistance due to the movement of the boundary can be known by measuring the potential across these tubes. Using an upper liquid having a conductivity slightly greater than that of the sol Dr. Mukherjee has found that the migration velocity of the colloidal particles can be measured by his modified apparatus fairly accurately. In a recent paper Dr. Mukherjee has again emphasised the sources of errors in the U-tube method and has shown that the ultrafiltrate is quite unsuitable as an upper liquid. However, Dr. B. N. Desai in a letter to the Editor of *Current Science* states that the dialysate with suitable additions of hydrochloric acid is a very convenient upper liquid for the measurement of charge on particles of thorium hydroxide sol.

The modified apparatus has been extensively used by Dr. Mukherjee and his students to measure the variation in the migration velocity of the particles of various sols when they are diluted to different extent and when varying amounts of different electrolytes, non-electrolytes and mixtures of non-electrolytes and electrolytes are added to them. Lately Dr. Desai has also used this modified apparatus to measure the migration velocity of particles in a gold hydrosol and sols of ferric and thorium hydroxides during their progress of dialysis.

(*ii*) *Adsorption of ions and of non-electrolytes by insoluble precipitates and colloidal particles*

The change of concentration in the surface layer of contact of two homogeneous phases is called adsorption. The adsorption of nonelectrolytes and of ions from solutions of electrolytes by insoluble precipitates has been extensively studied and it has been generally found that the results can be expressed by Freundlich's empirical equation

$$x/m = a\, c^{1/n}$$

where x is the amount of a substance adsorbed by m grams of an adsorbent, c the end concentration and a and n are constants.

The adsorption of ions of both the signs by insoluble precipitates and by colloidal particles during the precipitation of the sols has been largely studied by Dr. N. R. Dhar and co-workers with a view to explain the various observations in the coagulation of sols, such as acclimatisation, ionic antagonism and reversal of charge, discussed in other sections of this article. They have mainly employed analytical methods for this investigation and have, in general, found that (i) the greater the valency of an ion the smaller is its adsorption, (ii) for a given amount of an electrolyte its adsorption increases with dilution, (iii) the adsorption of an electrolyte is greatest when the precipitate is in the process of formation and (iv) the presence of one ion represses the adsorption of another, the amount of repression depending upon the relative adsorbabilities of the two ions and the adsorptive power of the colloid. They consider that the chief factor in adsorption is the chemical affinity of the adsorbent for the substance adsorbed.

From a consideration of the valency of the adsorbing ion Dr. Dhar and Dr. Chakravarti have derived an adsorption equation

$$a/A = \left(\alpha\mu/K\right)^{\frac{1}{n}} \Big/ \left\{ 1 + \left(\frac{\alpha\mu}{K}\right)^{\frac{1}{n}} \right\}$$

where μ = number of molecules striking a surface,
a = the amount adsorbed,
A = the maximal adsorption,
n = the valency of an ion,

and K and α are constants. This equation has been found by these workers to be in very good agreement with the experimental results. The maximal adsorption predicted in the equation has also been experimentally realised. The above equation also readily reduces to the logarithmic equation when the concentration of the adsorbed substances is small.

Dr. K. C. Sen has studied the adsorption of acids by precipitates of the hydroxides of iron, aluminium, chromium and zirconium. He finds that the adsorption of the fatty acids by freshly precipitated zirconium hydroxide increases with the ionisation constant of the acids and the logarithmic equation is, in general, obeyed. But the amount adsorbed per unit mass of the adsorbent has been found by him to vary with (i) the amount of the adsorbent, (ii) the volume and the concentration of the solution, (iii) the physical nature of the adsorbent and (iv) the temperature at which the adsorption is measured. It is also increased by the presence of non-electrolytes in some cases which shows that Weiser's contention of the lowering of the adsorption of an electrolyte by a non-electrolyte is not generally valid. The constants of the adsorption isotherm also vary with the nature and the physical conditions of the adsorbents. The adsorption is, according to Dr. Sen, caused by the surface chemical activity of the adsorbent for the substances adsorbed and the process of adsorption is similar in mechanism to the chemical combination taking place in salt formation.

Similar views regarding the combination of the adsorbed substances with the adsorbents have been advanced by Dr. S. S. Bhatnagar, Dr. D. L. Shrivastava and co-workers from the results of their study of the adsorption of sugars and sodium oleate by colloidal solutions and finely divided insoluble precipitates. They find that the adsorbed substances cannot be removed on washing the adsorbents with water and that in the adsorbed state, sugars lose their property of optical activity and sodium oleate no longer lowers the surface tension of water, although the presence of the elements constituting sugars and sodium oleate can be recognised in the adsorbents. From the magnetic susceptibility measurements of the adsorbents containing the adsorbed substances Dr. Bhatnagar and co-workers find that they become markedly diamagnetic even when both the adsorbents and the adsorbed substances are paramagnetic. They, therefore, conclude that the formation of a physico-chemical complex from the adsorbent and the substances adsorbed is within the region of the definition of chemical combination.

Dr. J. N. Mukherjee and co-workers have, on the other hand, studied the adsorption of ions by electro-osmotic experiments for which they have used a modified form of Brigg's apparatus. They find that (i) a well washed precipitate is not electrically neutral against water, (ii) the acids and alkalies have a marked effect on the charge on the surface of particles, (iii) both the ions are adsorbed by the precipitates and (iv) the adsorption of an ion by a precipitate containing the same ion is very great and leads to the reversal of charge on the precipitate.

According to Dr. Mukherjee one kind of ions of an electrolyte is primarily adsorbed at the surface of the adsorbent by chemical affinity and an equivalent number of the oppositely charged ions remains near the surface as the mobile second sheet or as electrically adsorbed. If the second sheet contains $H^{\cdot}$ ions or hydrolysable ions or if the surface is saturated with OH' ions, the $H^{\cdot}$ or the OH' ions can be displaced by ions of a neutral electrolyte when its solution is shaken with such a precipitate. The solution then becomes either acidic or alkaline. Such an adsorption has been termed "hydrolytic adsorption" by Dr. Mukherjee.

This kind of adsorption implies that the charge on the surface is due to the chemically adsorbed ions which are removable with great difficulty by washing. The $H^{\cdot}$ ions from the mobile sheet can be easily displaced by a neutral electrolyte in the following manner

$$\Big((BA)_x(H_2O)_yA'\Big)^{-}\overset{+}{H} + KCl = \Big((BA)_x(H_2O)_yA'\Big)^{-}\overset{+}{K} + HCl$$

where (BA) represents the precipitate containing A' ions which are primarily adsorbed. The precipitate thus acts as an acid, *i. e.* it is a source of H ions. Similarly if OH' ions are in the mobile sheet a treatment with a neutral electrolyte will give rise to OH' ions. These theoretical considerations have been verified by Dr. Mukherjee and co-workers in the case of various polar precipitates containing primarily adsorbed anions and cations and the important application of these considerations to the problem of the soil acidity has been indicated.

Dr. B. N. Ghosh has by the treatment of the hydrated manganese dioxide with various neutral electrolytes determined the number of $H^{\cdot}$ ions replaceable per gram atom of manganese and has shown on analysing the solution quantitatively that the gram atoms of cations adsorbed are equal to those of hydrogen liberated. He also finds that the order of the cations in replacing the $H^{\cdot}$ ions from the mobile layer is the same as that of their ionic mobilities.

(*iii*) *Coagulation of Sols*

On the addition of electrolytes the stability of a sol decreases and the colloidal particles coalesce to form bigger aggregates which settle out from the sol as large flocculi: the sol is then said to have coagulated. Professor Freundlich and Dr. S. K. Basu have shown that a mere agitation of a sol increases its coagulation by concentrated electrolytes having a high coagulating power but with dilute and weakly coagulating electrolytes the coagulation is retarded. Miss Sheila Roy, the only lady worker in India in the field of colloidal chemistry, has studied the effect of sunlight on various sols and finds that it has a coagulating effect on some sols.

Dr. J. N. Mukherjee has studied the question of the coagulation of a sol on the consideration of the adsorption of the oppositely charged ions of different valencies. He has shown that if the surface of the particles does not exert any chemical affinity on the ions of the added electrolyte, the maximum adsorption of ions of opposite charge corresponds to the neutralisation of the charge on the particles and depends upon the mobility of the ions. Thus the order of cations in coagulating negatively charged sols should be

$$Th > Al > Ba > Sr > Ca > Mg > H > Cs, Rb > K > Na > Li.$$

This order of the cations has been experimentally verified by Dr. Mukherjee in the coagulation of arsenious sulphide sol.

Diverse views exist regarding the effect of dilution and of the presence of an electrolyte and a non-electrolyte on the coagulation of a sol by electrolytes. Dr. N. R. Dhar and his school of workers find that (i) the amount of an electrolyte required to coagulate a concentrated sol is greater than that required for a dilute one and (ii) the relative order of the coagulating ions for the same sol changes as the concentration of the sol is altered. They consider that there are two distinct stages in the coagulation of a sol; the first one corresponds to the neutralisation of the charge on the particles and the second one to the adsorption of ions by the discharged particles. The Schulze-

Hardy law is obeyed only upto the first stage of coagulation and its apparent deviations are caused by the second process.

According to these workers the coagulation of a sol by electrolytes depends upon two factors: (i) the hydrolysis of the sol and of the coagulating electrolytes and (ii) the rate at which the electrolytes are added to the sol. The latter phenomenon is known as acclimatisation which may be either positive or negative and is ascribed by these workers to the inhibition of the hydrolysis of the sol and the adsorption of the similarly charged ions by the sol. The ageing of a sol, however, causes a decrease in the coagulating concentration of an electrolyte.

The coagulation of a sol by uni-, bi- and tri-valent ions is according to Dr. Dhar and co-workers proportional to $1 : \frac{1}{2}\alpha : \frac{1}{6}\alpha^2$ where α is given by $e - \frac{qeDr}{kT}$. Dr. S. S. Bhatnagar and co-workers have, on the other hand, examined the coagula of some sols obtained by coagulating them by uni-, bi- and tri-valent ions with a view to determine some relationship between their sizes. They find that the elutriation velocities required to separate the final size of particles in the three cases are approximately in the ratio 1: 2: 3.

When a sol is coagulated by an electrolyte in the presence of another electrolyte having the same coagulating ion as the former, the coagulating power of either ion is decreased. This effect of the common ion which is a particular case of the antagonistic effect or ionic antagonism, was first studied by Dr. Mukherjee. The ionic antagonism is explained by Dr. Dhar, Dr. Mukherjee and co-workers by (i) the adsorption of the similarly charged ions which increases the density of charge on the particles and (ii) the weak adsorption of one of the coagulating ions. On the consideration of the dilution effect and ionic antagonism Dr. Dhar has classified sols into two types, anomalous and normal. The anomalous sols are those which require more of the univalent ion for the coagulation of the dilute sol than of the concentrated ones: the coagulating power of electrolytes of different valencies is additive towards them.

The presence of non-electrolytes such as alcohols, acetone and others and of solutions of various sugars either decreases or increases the concentration of a coagulating ion. In the former case the sol is said to be sensitised. Dr. Dhar and co-workers have extensively studied the problem of sensitisation and have concluded that it is caused by (i) a decrease or a reversal in the charge of the particles and (ii), a repression of the hydrolysis.

Dr. J. N. Mukherjee and his students have, however, pointed out the necessity of simultaneous measurement of charge on the colloidal particles under the various conditions given above before any explanation for these phenomena can be attempted. They have measured the migration velocities of the particles under the above-named circumstances by their modified apparatus and find that the density of charge on the particles of a sol decreases when (i) the electrolytes and ethyl alcohol are added to it and (ii) the sol is diluted. But in the case of a sol to which a mixture of electrolytes is added they find that there is a rise in the charge when the concentration of one electrolyte is smaller than the other. Dr. B. N. Desai and co-workers working on the thorium hydroxide sol dialysed to different extent find that the presence of non-electrolytes affect the sol in the same way as its continued dialysis, that is, tend to reduce the potential of the particles. We have also found similar behaviour of the effect of alcohols in the case of ceric hydroxide sol.

Dr. Mukherjee and co-workers have further found that the stability of sols increases on dilution and for the same colloid content of a sol the one with coarser particles is more stable than that having finer ones. This increase in the stability has been explained by them to be due to the increase in the distance of the particles. Dr. Desai has also studied the effect of dilution, stability and coagulation by mixture of electrolytes on thorium hydroxide sol undergoing dialysis and he finds that Freundlich's view that ionic antagonism is a characteristic of hydrophilic colloids is not supported by his experiments.

In 1916 Smoluchowski derived an equation for the coagulation of colloids from the considerations ot the sphere of action of the coagulating ions. The equation has been experimentally verified by Dr. Mukherjee from the measurement of the rate of coagulation of the gold sol spectrophotometrically. He finds that the equation holds good in this case fairly well. Dr. Desai, however, finds that the equation applies to the coagulation of the thorium hydroxide sol only upto a certain concentration of the coagulator. He further finds from the study of the thorium hydroxide sol undergoing continued dialysis, that slow coagulation and the autocatalytic nature of the coagulation velocity curves as predicted on Smoluchowski's theory can only be observed when the sols are fairly concentrated and the potential of the colloidal particles is far away from the First Critical Potential of Freundlich (Dr. Mukherjee has shown from cataphoretic measurements that the coagulation does not necessarily take place at the critical potential). But Dr. S. S. Joshi and co-workers find from their study of the coagulation of antimony sulphide sol that the slow coagulation cannot, in general, be considered as autocatalytic.

(iv) Peptisation and reversal of charge on sols.

The phenomenon of bringing a coagulum or a precipitate into colloidal solution is known as peptisation. This can be effected by the addition of suitable non-electrolytes or by washing the precipitate with water or by boiling or stirring it in the presence of suitable electrolytes. It is fairly difficult to peptise the precipitates existing in a compact mass. Hence the study of peptisation has been confined to (i) the fresh precipitates obtained by coagulating a sol and (ii) the precipitates which would have been obtained by mixing the solutions of salts with alkalies or any other reagent which would give rise to an insoluble precipitate had the peptising agent been not present.

Dr. N. R. Dhar and his students have published a large number of papers on peptisation studied under the latter circumstances. Dr. N. G. Chatterjee has investigated the peptisation of several insoluble hydroxides formed by the addition of sodium hydroxide to the solutions of their salts in the presence of glycerine and sugars. The resulting solutions are found to be colloidal and consist of negatively charged particles. By measuring the electrical conductivity of a solution of sodium hydroxide in the presence of these insoluble hydroxides Dr. Chatterjee has shown that these are the true cases of peptisation and not of chemical combination. Dr. Dhar has further found that complex ion formation precedes the formation of colloidal solution which is due to the affinity of the peptising agent for the insoluble substances.

The colour of solutions of copper salts containing excess of ammonium hydroxide or tartarate or other organic substances has been attributed by Dr. Dhar and co-workers to the formation of colloidal copper hydroxide in these solutions. These observations have been experimentally verified by Dr. Bhatnagar and co-workers by the similarity of the absorption spectra of these solutions and of a colloidal solution of copper hydroxide.

Dr. K. C. Sen and Mr. M. R. Mehrotra have studied the peptisation of metallic hydroxides in the presence of various sugars. They find that at low concentration of salt solution there is a direct proportionality between the metallic hydroxide peptised and the sugar added. They have collected evidence to show that the salts of metals with sugars are not formed in these cases. But sugars alone cannot peptise the hydroxides : a certain amount of OH' ions, more than that required for the complete precipitation of the hydroxides, is also necessary. However these ions alone cannot peptise the hydroxides. The peptisation is brought about by the ions which are first adsorbed whereby the particles of the hydroxides disintegrate and acquire a certain charge, the sign of which depends upon the peptising ion. But the efficiency of peptisation of the same electrolyte and non-electrolyte depends upon the nature of the adsorbing substance and the selective tendency of the substance for the peptising ion. The rôle of non-electrolyte in this case is, however, not yet clearly understood.

In what is described above it is clear that the addition of a non-electrolyte prevents under certain conditions the formation of a precipitate. Similar phenomenon is observed when certain electrolytes are added to a colloidal solution; instead of the particles of the sol separating out as a coagulum they remain in the colloidal state. Cataphoretic experiments have revealed that in these cases the charge on the colloidal particles is reversed.

Dr. Mukherjee has explained the reversal of charge on the consideration of the two types of adsorption of ions (i) the chemical or primary adsorption of ions at the surface of the particles and (ii) the electrical adsorption of oppositely charged ions in the double layer. On the addition of an electrolyte the oppositely charged ions enter the double layer and are driven to the surface by strong electric field and are held near each primarily adsorbed ion by electrical forces. The maximum number of ions which can be so held per unit surface is equal to the number of primary ions in the same surface. These ions will, therefore, impart a maximum charge $NE\ (n_1-n_2)$ to the surface, where N is the number of primary ions, E the electronic charge and n_1, n_2 the valency of the primary and oppositely charged ions. It is clear from the above expression that the reversal of charge can in no case be brought about by the univalent ions, if the chemical affinity of the particles for the ions is negligible.

Dr. N. R. Dhar and co-workers have extensively studied the reversal of charge in a large number of sols by different electrolytes. They find that the adsorption of oppositely charged ions by the colloidal particles plays a very important part in the reversal of charge. This view is supported by their observation that the charge on some sols is reversed even with univalent ions which, they find, are strongly adsorbed by the colloidal particles. These ions, according to Dr. Dhar, exert a peptising influence on the particles and their behaviour runs parallel to the coagulating power for the sol containing particles charged oppositely to these ions.

(B)—EMULSIONS

Disperse systems in which both the disperse phase and the dispersion medium are liquids are called emulsions. They are prepared by shaking the two liquids, usually water and oil together in the presence of a third substance known as an emulsifying agent or an emulsifier. According as the dispersion medium is water or oil, two types of emulsions—oil-in-water and water-in-oil—are possible.

The largest contribution to the study of emulsions from India is by Dr. S. S. Bhatnagar and his students and most of this work is described in details in *The Theory of Emulsions and their Technical*

Treatment by William Clayton (1928). Previous to Dr. Bhatnagar's researches on emulsions the type of an emulsion was determined by the indicator and the drop dilution methods. Dr. Bhatnagar has pointed out the disadvantages of these methods and has found that the electrical conductivity method is very sensitive for determining the type of an emulsion. If an emulsion is a good conductor, it is of the oil-in-water type ; if not, it is of the reverse type.

Dr. S. S. Joshi has found that the surface tension of the two types of emulsions has the same value as the dispersion medium. He has also measured the viscosity of the two types of emulsions and finds that it is independent of the concentrations and the nature of the emulsifying agents but it increases as the ratio of water to oil is increased and falls rapidly as the emulsion is inverted to oil-in-water type. He has, therefore, suggested that these measurements can also be used to determine the type of an emulsion.

Dr. Bhatnagar has used the electrical method in the study of the inversion of the type of emulsions when the volume ratio of the two phases is changed and when suitable electrolytes are added to the emulsions. He finds that the volume ratio, 74 : 26, at the inversion point found by other workers holds good only when the aqueous phase is slightly alkaline. With alkalies of higher concentration he finds that higher ratios are possible and they are due to the formation of a solid or gelatinous film around the oil globules.

Emulsions were prepared by previous workers from oils containing free acids and alkalies as the emulsifying agents. But Dr. Bhatnagar pointed out that the presence of free acids and alkalies causes considerable complexities in the emulsions. He consequently employed for his studies the emulsions stabilised by various soaps and by finely divided insoluble oxides of lead and aluminium and some insoluble organic substances. He showed conclusively that there is a distinct valency effect of the electrolytes in inverting an emulsion. He further showed that (i) greater amounts of multivalent ions are needed for inverting an emulsion as it is more and more diluted and (ii) the inverting power of ions is the same as that theoretically determined by Dr. Mukherjee for the precipitation of negatively charged sols. He thus established clearly the analogy between emulsions and colloidal solutions.

Dr. Bhatnagar finds that a zone of instability precedes the inversion and this zone is clearly seen when sufficient emulsifying agent is present. He has formulated two rules which are known as Bhatnagar's Empirical Rules regarding the inversion of emulsions: (i) "An emulsion of water-in-oil can be transformed into one of oil-in-water by electrolytes having reactive anions like OH' and PO_4''' (ii) an emulsion of oil-in-water can be transformed into the reverse type by electrolytes having reactive cations like $H^{\cdot}$, $Al^{\cdot\cdot\cdot}$, $Fe^{\cdot\cdot\cdot}$, and $Th^{\cdot\cdot\cdot\cdot}$."

Dr. N. R. Dhar and Dr. S. Ghosh have sudied the influence of ions carrying the same charge as the dispersed particles on the inversion of emulsions. They find that the coagulation and the inversion of an emulsion, the abnormal dilution effect and the antagonistic effects observed with monovalent cations are due to the adsorption of ions and are fundamentally connected. They have substantiated their views by showing that the curves obtained by plotting log (concentration of soap solution) against log (concentration of electrolytes effecting inversion) are straight lines. A reference to the work of these authors on colloidal solutions shows that they have explained similar behaviour in these solutions on similar considerations. These investigations, therefore, are of great value in demonstrating the resemblance between an emulsion and a colloidal solution.

The main factor determining the type of an emulsion was considered by Pickering to be the preferential wetting of the emulsifying agent by the oil or water. Bancroft has suggested that the type of an emulsion can be determined by the solubility of the emulsifying agent in oil and water. Dr. Bhatnagar has generalised that all emulsifying agents having an excess of negative ions and wetted by water will yield oil-in-water emulsion, while those having an excess of adsorbed positive ions and wetted by oil will give water-in-oil emulsion. He has also collected evidence to show that emulsification is governed mainly by two factors (i) the relative wetting power of the two phases with respect to the emulsifying agent and (ii) the surface potential of the membrane between the phases. The reversal of phases by electrolytes is brought about by the changes produced in the membrane with regard to either or both of these phases. The efficiency of the soaps which favour the formation of an oil-in-water type of emulsion has been found by him to decrease in the following order:

potassium stearate > sodium stearate > sodium and potassium palmitate > potassium oleate > sodium oleate.

(C)—GELS

The term gel was originally assigned to the precipitate or coagulum obtained on coagulating a sol. But now the term is applied to colloidally disperse structures consisting of a solid and a liquid phase and having shape and cohesion, that is, elastic properties.

The study of gels in India was first undertaken by Dr. N. R. Dhar and his students. Dr. Dhar has classified the jellies into three groups: the jellies of starch, gelatin, vanadium pentoxide and ceric hydroxide belong to the first group, those of the hydroxides of iron chromium etc. to the second and von Weimarn's jellies to the third.

Mr. Prakash and Dr. Dhar have prepared a large number of tungstate, molybdate, phosphate, arsenate and borate jellies for the first time. They have studied the conditions of setting of the above named jellies and of those of metallic hydroxides which they have prepared by a slight modification of the methods used by other workers. From the measurements of viscosity and the $H^{\cdot}$ ion concentration of the inorganic jelly-forming mixtures during setting and the study of the influence of temperature on gelation and syneresis they have shown conclusively that there are three stages involved in the process of setting of these jellies: (i) the formation of colloidal particles by the adsorption of similarly charged ions, (ii) the coagulation of the particles by the adsorption of oppositely charged ions and (iii) the formation of specific structures.

These authors have put forward definite views regarding the conditions for the formation of a jelly. They distinguish between the two tendencies of a precipitate obtained by coagulating a colloidal solution: (i) the agglomeration tendency which brings about an increase in the size of the particles and (ii) the hydration tendency. According to them the jellies can only be formed when the agglomeration is either negligible or is comparatively much smaller than the hydration: the jellies formed under the former condition are transparent and remain as such for a long time and those formed under the latter circumstances are either opaque or opalescent.

We at the Royal Institute of Science have studied the formation of the silicic acid gels prepared by Bhatnagar and Mathur's method and by mixing solutions of sodium silicate and of various acids. Mylius and Groschoff have shown that when the gel-forming constituents are mixed crystalloidal silicic acid is formed but it rapidly polymerises and goes over to the colloidal state. Dr. K. Krishnamurti has also shown by the measurement of the intensity of the light scattered by these mixtures that the primary particles are first formed in the mixtures. The charge on the colloidal silicic acid has been shown by us to be positive or negative according as the silicic acid is formed in an acidic or alkaline mixture. These results are in agreement with the observations (i) of Billiter who finds that the particles in a silicic acid sol are charged negatively in an alkaline and feebly acidic solutions and positively at higher hydrogen ion concentration of the mixtures and (ii) of Lösenbeck who has shown that these particles are originally negatively charged and the charge decreases, reaches an iso-electric point and then becomes positive in the presence of increasing amount of hydrochloric acid.

We have also shown that the next process in the gelation is the coagulation of the colloidal silicic acid by the electrolytes formed in the mixture by (i) the similarity of the behaviour of the added electrolytes and non-electrolytes on the gelation of silicic acid and the coagulation of the dialysed sol of silicic acid and (ii) the application within certain limits of Smoluchowski's equation of coagulation to the gelation of silicic acid. As the coagulation of the silicic acid sol proceeds, the viscosity of the gel-forming mixture increases very slowly at first and then very rapidly. The increase in viscosity is caused by the decrease in the charge and increase in the size of the colloidal particles. The continuous nature of the time-viscosity curves shows that the formation of crystalloidal silicic acid, its going over to the colloidal state, the coagulation and agglomeration of the particles and the change in hydration and the linking of the hydrated particles do not take place in definite and distinct steps.

The time of setting of silicic acid gels has been measured by Fleming by the criterion that the vessel containing the gel-forming mixture can be inverted without the gel flowing out. Fells and Firth find that the setting time is given by the maximum pressure required to blow in or suspend through the mixture a bubble of air or of mercury or of chloroform coloured with iodine. But we have shown that these methods are not accurate and involve errors due to the disturbance produced in the setting mixtures. These errors are obviated in the optical method which has been used by us for the purpose. We find that the mixtures having *pH* near about 7 set in minimum time and have consequently advanced a view that the minima observed by previous workers can be explained on the variation in the nature and the density of the charge on the colloidal particles.

The set gel emits a note whose pitch increases with the removal of the dispersion medium. From the measurement of the frequency of the note and the elasticity of gel it has been shown by us that the set gel behaves as an isotropic substance. However the gels setting from mixtures of various *pH* differ from each other in appearance. In general the alkaline gels are opaque and appear bluish in reflected light while the acidic ones are translucent and appear pinkish white. The rate of the loss of water from these gels has also been found to depend upon the acidity and the alkalinity of the mixtures. From the similarity in the behaviour of the silicic acid gels with that of emulsions with respect to the coagulation, the reversal of charge, the differences in the appearance and some properties of the two types of gels it appears reasonable to regard these gels as emulsions, a consideration which was first put forward by Wo. Ostwald. If this analogy is carried still further one may expect the two types of gels formed from positively and negatively charged sols to behave like two types of emulsions, at least in respect of the surface structure.

Professor N. A. Yajnik and his students are systematically studying the elasticity, resistance to cutting, surface reflectivity, extinction coefficient and absorption spectra of various inorganic and organic gels with a view to arrive at some definite conclusions regarding the setting and the structure of gels. The problem of the formation of gels has been studied by Dr. K. Krishnamurti from a different point of view. He has measured the intensity and the depolarisation of the light scattered by the gels during setting. He finds that on cooling the agar solution the colloidal particles of agar form bigger aggregates and the set gels contain micelles which are bigger than those present in sols at the same temperature. The increase in size of the micelles during setting does not necessarily take place in all gels: Dr. Krishnamurti has succeeded in preparing sols and gels of soaps which contain particles of identical size as evidenced by the intensity of light scattered by them. These micelles in a sol according to his results are surrounded by a hydration layer and the union of these hydrated micelles is a sufficient condition for the formation of a gel. From the measurements mentioned above he has also been able to explain the swelling of gelatin gels when they are placed in water.

CHEMICAL REACTIONS IN GELS

When one reacting substance is dissolved in a gel and another substance which gives an insoluble precipitate with the first one is placed at the top of the gel after it has set, it has been observed by Liesegang that there is a copious precipitate at the surface of contact of the two substances and then the precipitate appears at some distances separated from each other. The distances between each layer of the precipitate increase as the distance of the layer from the top is increased. These rings are called Liesegang Rings after the name of their discoverer.

The formation of these rings has been ascribed by Ostwald to the supersaturation of the insoluble substance followed by precipitation. Bradford, on the other hand, considers that the substance dissolved in the gel is adsorbed by the precipitate and thereby a certain portion of the gel is rendered free from the reacting substance. Dr. Dhar and Dr. A. C. Chatterjee have explained the formation of the rings on the peptising influence of the gel substance on the insoluble precipitate and the coagulating effect of a precipitate and an electrolyte on a sol. They have thus succeeded in accounting for the formation of the two types of rings (i) in which the clear spaces are free from the reacting solutions and (ii) those having peptised solutions in between the rings consisting of coagulated and crystalline matter.

The above explanation has been confirmed by these workers by separate experiments on the peptisation of the insoluble precipitates by the gel-forming substances and the adsorption of the electrolytes and the colloidal solutions by them. By E. M. F. and electrical conductivity measurments they have also come to a definite conclusion that the insoluble substance in the gel exists in the colloidal state. But from similar measurements Dr. Desai and Mr. Nabar have concluded that most of the insoluble substances in the presence of gelatine exist in the ionic state.

Dr. Dhar and Dr. Chatterjee have succeeded in obtaining Liesegang rings with a large number of insoluble precipitates for the first time. These workers and students working in Dr. Bhatnagar's laboratory have also obtained rings when solutions of electrolytes are allowed to diffuse through gels impregnated with sols. Mr. R. N. Mathur from Dr. Bhatnagar's laboratory has found that the logarithms of the distances of the rings of the same ordinal number for different concentration of the diffusing solutions are inversely proportional to the cube root of the concentration.

The object of this article has been to give an account of the more important conclusions drawn by various investigators in India from their study of the various problems in colloidal chemistry. It has not been possible to touch on all the problems of colloidal chemistry which are receiving attention from Indian Research Workers but the bibliography given at the end of this article is, it is hoped, complete to date.

I wish to express my thanks to Mr. Jagdish Shanker, B. Sc., who has assisted me in preparing the bibliography, some of which has been taken from the Presidential Address of Professor S. S. Bhatnagar to the Chemistry Section of the Indian Science Congress, 1927. I am also thankful to Mr. S. M. Mehta, B.A., M.Sc., for his assistance.

PAPERS ON COLLOIDAL CHEMISTRY FROM INDIA

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CHEMISTRY AND INDUSTRY

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Professor of Chemistry and Industrial Chemist to the Government of Baroda

It has been a common complaint from all sides, specially from industry, that the University is turning out graduates in Science who have failed to come up to the expectations entertained of them. The University has to a great extent been blamed for this. Though there is some truth in this, it is not the whole truth. It is not the training that is really at fault. It is because the training of the graduates, as required by the industries, is *incomplete.* That is the real cause of the complaint.

In any science subject as at present taught, the Universities in India have organised courses in theory which can be compared to any obtaining in the best universities of the world. The amount of practical work demanded of these graduates is also planned on a broad basis. What is wanted is the opportunities for the specific application of this broad-based theoretical and practical preparation to specific industries. A student wanting to join a Public Health Analytical Department should have to take additional training in the specific methods of food analysis; another wanting to join the dyeing and printing department of a mill should have to take specific training in the applications of the various methods obtaining in that line, from a scientific and practical point of view. The broad-based undergraduate training prepares the ground on which the specific training required for the industries could be based. Without this most necessary fundamental ground work, the experience gained by any worker in any industry would be a mere rule of thumb matter. If what the present graduate possesses is supplemented by a broad-based general acquaintance wlth special engineering principles which come to find application in industries, together with a specific training required for the particular industry, the industries would get an excellent worker. A band of such completely trained men, working under the direction and guidance of a well-experienced professor or director, would be a powerful force to the industries.

"To-day is a time of revolution, a time, perhaps, rather of evolution, a fact plainly to be seen by those chemists and commercialists whose eyes are open" says Dr. Lampitt, in his lecture before the Institute of Chemistry. "We have had the steam revolution, the electrical revolution, and now the chemical revolution, the change from rule of thumb to scientific control." One would think that it is time for us in India to call a temporary halt and to take stock of all the achievements in chemistry with a view to balance our accounts, and to scrutinize the profit and loss we have made, so that when we discover, as we trust we will, that the balance sheet discloses a profit, we may the more courageously be able to outline and even launch out into further projects making for progress and prosperity. It is a fact which we all deplore that there are many men in chemistry to-day in India who are not chemists by instinct. It often happens, when it becomes necessary to decide on a career for a young man, that some one mentions to his parents that there are good openings in chemistry, simply because certain professions such as law, medicine, etc., are overcrowded. Consequently, the young man becomes a chemist; he is so to say driven into chemistry or more correctly drifts into it. He then expects a career in industrial undertakings, but the fact that in industry one must be more of a specialist than in other walks of life, is often lost sight of by the young man. To be useful to industry, he must possess a precise and at the same time a wide knowledge of the whole range of chemistry. He must not only be an organic chemist, a bio-chemist, a physical chemist ; he must be a chemist—one who can calculate production costs, can translate bench experiments to factory scale; and he therefore must know something of heat transference, of the flow of liquids and of a multitude of other details cognate to his work. He must make it his business to study branches of science outside the immediate or proximate needs of his job. Very often it happens that a post-graduate student applies for a job as an industrial chemist claiming to be particularly fitted for research. Such a one does not realise that the routine carrying out of the ideas of other people does not constitute a claim to be called a research worker; and he must not be surprised to find that the world outside his college laboratory, treats him with a certain amount of coldness and want of sympathy.

Those of us who have some experience of industries in India, and have come to know the outlook of a purely technical man, the man who has always done a job in one particular way, and is not particularly anxious to do it in any other way, can realise the difficulties which a scientific man has to overcome when he is confronted with the above type of employer, and the more so if he happens to be a successful *entrepreneur*. It is unfortunate that millionaires in our country have too generally entered upon their careers without a proper appreciation of scientific work. They want returns and fail to understand the toil that must precede the harvest. " It is not so easy to develop scientific results, as to grow an orchard," says Prof. Bragg.

We have often heard the argument put forward in opposition to some new proposal, that " the old method has done very well all these years, why go to the trouble and expense of altering it". Let us examine this. There is the textile industry ; world competition in it is very keen, and its percentage of profits is rapidly dwindling. If it is to hold its own, there is an absolute necessity to cheapen the cost of production, and to save on labour charges ; and yet in our country there is no organisation worth the name, for calling in the aid of science to bring about these desiderata. The country would profit immeasurably if it were to realise that the successful businessman of the future will have to be a scientist or at least have some scientific training. One of the most important facts which has contributed to the rise of industries in Germany is that some of the men at the head of the chemical industries are chemists of no mean ability who can think in terms both of chemistry and business—an art not easily acquired. Such men can build up industries with a broader perspective, greater permanency, and a feeling of congeniality towards their work.

In our country the industrialist of to-day is very much at the mercy of the quasi-scientist and is often led into the commission of costly errors, the fruit of haphazard methods and lack of knowledge or judgment of the pseudo-scientific adviser. Can such an *entrepreneur* be blamed if, after his costly experience, he is never eager to take fuller advantage of the assistance of the scientist ? In some cases the shyness of the industrialist might be due to the scientist himself, for often one notes a tendency in him to maintain an air of mystery and aloofness. The result is that hopelessly garbled and inaccurate announcements are issued by the non-technical press which usually make the experienced businessman not a little sceptical and suspicious and as a consequence he is not prepared to spend the large sums necessary to advance discoveries which would ultimately bring him an adequate return for his outlay.

In America and Germany scientific assistance in commerce has developed much more rapidly than in other countries. It is imperative that in India the scientist must come down from his perch and get to grips with the hard facts of commerce. He must come out of his laboratory, his test-shops and his offices for part of the time and get into touch with the people, workers, managers, directors, and others who have to earn their living by making and selling goods competitively. The future Head of our Chemical Technology Department should never be allowed to lose sight of this fact.

The interests of pure science are themselves bound up with the commercial applications of the results achieved by research. Industry will foster research, if it is convinced that it will benefit itself directly, as a result of experiment and research. Science must be made to pay its way. A businessman will only be convinced of the need for scientific research if a trading account is produced, showing clearly in figures the profit that will accrue to the industry from the employment of a researcher, and the disadvantages that would follow from failure to do so. No other method will convey to him the exact value and utility of research work.

A businessman often expects something more from the chemists, over and above his scientific ability and knowledge. Efficiency and economy are no less essential to the success of industry than control of quality and cost of manufacture. The chemist will, therefore, prove himself of greater utility if he gets out of the laboratory and is prepared to take some share in departmental management also. For this, he may have to acquire a working knowledge of book-keeping and accountancy and organisation. He may have to cultivate tact and personality to handle men to get the best out of them, as well as initiative and forethought. All this means desperately hard work, but it is worth doing.

The Universities in our country are on the whole manned by a competent class of research workers who have contributed in no small degree to independent investigations on research problems in pure science, but I am sorry to say that the staff has rarely been able to come in close contact with the industrialists. This contact is a necessary preliminary to development of the existing or the initiation of new processes in industry. We, University men, engaged in the alluring pursuits of conducting research, should not forget that we owe a duty to our country. It would appear that we have not yet fully realised what a loss it is to us and to our country, in not establishing very close contact with our industrialists. I know full well that they want our full co-operation and we want them to appreciate our noble pursuits ; and yet there is a distance between us. Let me, therefore, suggest a way of closer co-operation between industrialists and ourselves. This can easily be achieved through our universities. Some of the older and some of the newer Universities have been fitted with first rate laboratories for scientific research. What is wanted is a sincere effort to inspire confidence among the industrialists. I would suggest that our fellow researchers should come out of their laboratories, join the various Mercantile Associations and have a heart to heart talk with their members. We should try to popularise our science and make the public interested in our work. The industrialist will slowly realise the importance of our work and try to go with us. Professor Duncan of the Mellon Institute had the same initial difficulties, but the record of work over a dozen years speaks for itself. We owe a duty to the country and God forbid that we should be found wanting when we ourselves are weighed in the delicate scales of public opinion. Once the Mercantile Associations get to know of our earnestness and willingness to help them, they will, with confidence, entrust their industrial difficulties to the Universities where research workers could try to solve them, by what may be called *ad hoc* research. To achieve the end in view, the Universities in each province, besides providing complete equipment and apparatus for studies in the fundamental subjects, such as physics, chemistry, mathematics, chemical engineering, biology, etc., should also be fitted up with a complete set of semi-manufacturing scale equipment, for investigation and research in the problems of the principal industry or industries of that province. Let me take a concrete instance. The Bombay University should have a Department of Applied Chemistry, which besides being fitted up with complete equipment and apparatus in the fundamental subjects enumerated above, should make full provision for industrial training and research in Textile Chemistry. The other Universities should also make a move in a similar direction. The tremendous importance of the step the Bombay University has taken in deciding to equip the Department of Chemical Technology, will now be apparent to the readers. In view of what is stated before, regarding really useful industrial training, the necessity of a training in Chemical Engineering will be clearly evident. The University should carefully nurse this department and watch its development. It should aim at nothing less for the Head of such a department than a man who, on the one hand, should be a first rate chemist, and, who, secondly, have had real experience in the works themselves of the application of chemistry to the control, improvement and development of manufacturing processes. The teachers of pure science and applied science should be kept together for all their deliberations in a single board of teachers. For, as Prof. Smithells puts it, "One should never feel while studying or teaching, that here ends pure science and here begins applied science."

The University of Bombay has accepted the principle of instituting several Diploma courses. The industries are waiting for this properly qualified lower class of men to help their departmental processes under the guidance of experts. There are institutions in the presidency which are preparing such type of men but maintain different standards of qualifications for their diplomas. The employers of such men are at a loss to know very often as to what they are paying for, when they employ these men. Formidable calendars from these institutions often mislead employers to think that the courses laid down therein are efficiently completed. Experience has taught them to be more careful recently. It is, therefore, the clear duty of the University as the highest authority in education, to hold examinations in the courses for the various diplomas which it would institute and thus supply standard men to the industries. It will also bring institutions in a line as to efficiency in equipment and maintenance of a definite standard of teaching and practice of the students trained by them.

A new era has been dawning for us. Very soon we may be called upon to organise ourselves in the service of our country. Let it not be said, when the call comes, that we were found unprepared to join in the country's march towards national progress, prosperity and peace.

Summaries & Abstracts of M. Sc. Theses for 1931-32

PHYSICS

I.—*Studies in Barkhausen Effect.* By V. D. DABHOLKAR,[*] M.Sc. (Department of Physics, Wilson College.) Guide: Prof. H. J. Taylor.

The paper contains a general bibliography on the subject of the Barkhausen effect and it also describes an experimental study of the same effect on ten specimens of steel, carried out acoustically and by means of Oscillograph records. The following observations are made in the paper :—

1. There is an approximate relationship between the Barkhausen effect and the slope of hysteresis curve.

2. The discontinuities are more distinct and more prominent during magnetization than during demagnetization.

3. The first large discontinuity occurs at a critical value of the magnetizing field which is constant and reproducible for any one specimen.

4. A slow rate of change of field gives larger but fewer discontinuities than a rapid rate of change.

5. The discontinuities are frequently observed to occur in different groups.

6. Values of v, the average elementary molecular volume associated with each discontinuity, have been calculated and found to be of the order of 10^{-4} c. c. within 15%, constant for all specimens, indicating that v is independent of the constitution.

7. The values of v do not have a random distribution but fall into groups suggesting three possible values.

8. No satisfactory relationship has been traced between the Barkhausen effect and the magnetic constants of the specimens.

G. R. P.

II.—*Some Experiments on Evaporation with Continuously Recording Apparatus, with special reference to its relationship with other meteorological factors and the dimensions of the evaporating tank.* By H. M. WADIA, M. Sc. (Meteorological Observatory, Colaba). Guide: Mr. S. K. Banerji.[*]

The object of the investigation was to determine the precise manner in which various factors influence evaporation and also to examine how it varies during the twenty-four hours of the day in a tank completely exposed to the Sun. Accordingly two self-recording evaporimeters were prepared locally and set up to record the evaporation from a tank specially constructed for the purpose. A series of carefully designed laboratory experiments in which only one meteorological factor was made to vary at one time was also carried on. To avoid edge effects each tank was placed inside another tank so that it was completely surrounded by water on all sides. The records furnished by the two independent self-recording instruments gave almost identical changes in the rates of evaporation. Typical curves showing the rates of evaporation every hour and their relationship with various meteorological elements have been given. The evaporation curves present one pronounced maximum in the afternoon. The exact instant when this maximum occurs does not coincide with the time of maximum wind velocity, or maximum temperature, or lowest humidity, but with the time when the combined influence of all these factors is the greatest. A close relationship was found between the intensity of the ripples and the rate of evaporation. These and other results have been discussed in the paper with particular reference to the dimensions of the tank and the eddy viscosity.

G. R. P.

III.—*A Case for the Colloid view in the Problem of liquid Sodium-amalgam.*

By R. M. JOSHI, M. Sc. (Department of Physics, Royal Institute of Science, Bombay.) Guide: Prof. G. R. Paranjpe.

(1) An account is given in the theoretical part of the paper of all available facts about liquid sodium-amalgams and it is attempted to show that, unlike the other theories the colloid hypothesis explains them satisfactorily.

In the light of the colloid hypothesis the conclusion is drawn:

(i) that liquid sodium-amalgams are lyophillic (hydrargyrophillic) sols of sodium in mercury with $Na_x\ Hg_y$ as the colloid micellae with varying values of x and y,

(ii) and that an amalgam is not completely defined unless the method of preparation, the age, and the previous history are also stated together with the concentration of sodium.

(2) In the experimental part the stability of amalgams of various concentrations ranging from 0·0274% to 0·1406% of sodium is studied, by keeping them in a vertical tube with many spouts undisturbed for over a week and analysing the contents at different spouts. It is found that all these amalgams keep homogeneous in bulk and show no tendency towards separation of sodium even in the neighbourhood of the lower concentration (0·079%) where each of the viscosity-concentration, density-concentration and

electrical conductivity-concentration curves are known to possess a discontinuity.

(3) The third part discusses the lack of sedimentation observed as a result of the experimental work in the light of the colloid hypothesis. It is attempted to show with the help of Stokes' law for sedimentations velocities, that the probability of the systems *Na-Hg* being lyophillic is greater than that of their being lyophobic.

G. R. P.

IV.—*Further Study of the Condensations of Water-Vapour on Nuclei with Special Reference to (i) the Numbers of Nuclei taking part in the Cloud Formation, (ii) the Velocity of Falling Drops, and (iii) the Transmission of Light through Clouds.* By Y. G. NAIK, M. Sc. (Department of Physics, Royal Institute of Science, Bombay.) Guide: Prof. G. R. Paranjpe.

The work was taken up in the first place to investigate the effect of the number of nuclei on the size of the drops forming a cloud. It was found that the size of the drops can be controlled at will and hence some other problems based on the knowledge of the size of the drops were also investigated.

The main results obtained are :—

(1) The size of the drops in an expansion is largely influenced by the number of nuclei present. As the nuclei go on increasing the size of the drops goes on diminishing for a particular expansion ratio and temperature.

(2) The growth of the drop with increasing expansion ratio where the number of nuclei was exactly the same is continuous. At higher expansion ratios, the growth becomes considerably slow and is likely to be mistaken as abrupt.

(3) An experimental estimate of the correction for the Stoke's law is obtained and results arising out of it have been discussed.

(4) Transmission of light through clouds is studied and it was found that for the same density and the same colour of light, the transmission ratio depends on the size of the drops. The relation between the size of the drops and the transmission ratio is exponential.

(5) A method of counting the number of dust nuclei in air is developed, and it appears that that method has many advantages over the existing dust counters. In this connection it has been shown that generally all the nuclei (unless they are not exceedingly large in number) are used up in the formation of drops in any expansion.

G. R. P.

V.—*Magnetism and Molecular Structure.* By M. B. NEVGI, M. Sc. (University College of Science, Lahore.) Guide: Dr. S. S, Bhatnagar.

In this paper the magnetic properties of a large number of organic and inorganic compounds have been experimentally determined and an attempt has been made to see if the results so obtained are compatible with the accepted views on their molecular structure.

In part I, the magnetic susceptibilities of a few groups of geometrical isomers have been investigated. In a pair of geometrical isomers, one compound is plane symmetrical and the other is axially symmetrical as illustrated by the structural formulæ for fumaric and maleic acids. According to the reasoning employed by Bhatnagar and his co-workers, in the case of position isomers, the former should be less diamagnetic than the latter. Experimentally it has been found to be the case.

Other *cis* and *trans* compounds are also found to behave similarly. A magnetic study of the geometrical isomers, therefore confirms the conclusions arrived at by entirely different methods about their molecular structure.

In part II, the magnetic susceptibilities of a few groups of allotropic modifications have been studied. An attempt is made to explain the different diamagnetic properties of the different allotropic modifications of sulphur on molecular orientation assumed by Foex and Royer in the case of nematic substances. In the case of other allotropic modifications it has been found that whenever there is a difference between their crystalline structure, as revealed by their X-ray study, there is a difference in their diamagnetism as well and not otherwise.

In part III, the magnetic susceptibilities of a few groups of polymers have been studied, and the results lead to the conclusion that polymerization is always accompanied by a decrease in diamagnetic susceptibility.

In part IV, the influence of temperature on the diamagnetism of some organic liquids has been investigated. The results obtained support the view that the diamagnetism of aromatic liquids, which are known to be highly anisotropic, tends to decrease a little with temperature while there is no such change in the case of aliphatics.

G. R. P.

VI.—*On Discontinuous Fluid Motion under Different Thermal Conditions.* By V. M. GHATGE, M. Sc. (The Royal Institute of Science and the Meteorological Observatory, Bombay.) Guide: Dr. S. K. Banerji.

The work of Prof. Prandtl and others shows that a surface of discontinuity in a fluid is unstable, that it changes into waveform and the waves finally develop into three-dimensional vortices. The discontinuity may be one of motion, or of density, or both. While considerable work has been done under laboratory conditions regarding the phenomena involving discontinuity in motion only, very little work appears to have been done when there is discontinuity in density or both in motion and density. In the present paper an investigation has been made of the phenomena observed at and in the neighbourhood of a source of discontinuity of the latter class.

A discontinuity in density was introduced by making a cylindrical or a rectangular column of water in a large tank to have different temperatures from the adjoining liquid, while a discontinuity in motion as well as density was introduced by making two streams of water under different thermal conditions meet each other at various angles. In both cases the surface of discontinuity resolves itself into interesting patterns of three-dimensional vortices. The mechanism of these vortices, the relationship of their dimensions, vorticity, etc. with the temperature difference at the surface of discontinuity and its slope, the depth of liquid as well as the velocities of the incident currents and other factors have been studied in the paper by photographing in horizontal and vertical sections the stream lines obtained by colouring various parts of the liquid and by other measurements. The paths of the particles at the surface of discontinuity have been photographed by a special method.

The instability makes each crest or a trough to take up the form of a breaker and the roll round itself. A succession of spiral shaped vortices are thus produced. In the directions of motion, the vortices show a progressive increase in dimensions and number of convolutions. The greater the difference of temperature at the surface of discontinuity, or the greater its slope, the smaller is the diameter of the vortices. For very small differences of temperature the vortices have enormous diameters. The greater the difference of temperature at the surface of discontinuity, the more rapidly the vortices develop. Qualitative explanation of most of the results have been given by simple hydronamical method or by means of the theory recently developed by Rosenhead.

G. R. P.

VII.—*Raman Effect in some Organic Esters.* By K. S. SAVANUR, M.Sc. (Department of Physics, Royal Institute of Science, Bombay.) Guide: Prof. G. R. Paranjpe.

The paper deals with the experimental work carried out in connection with the study of the Raman effect on 14 organic esters. The esters were :—acetates, formates, propionates, and butyrates.

(1) These results along with those of Dadien and Kohlrausch complete a homologus series of esters. Various linkages like the *C-H*, *C-O*, *C:O*, CH_2-group and *C-C* are studied. It has been suggested that the frequencies

characteristic of the inner oscillations are not greatly influenced by the surrounding conditions in a molecule, as seen in the values characteristic of $C\text{-}H$, $C\text{-}O$, $C{:}O$. On the other hand values obtained for CH_3-group.

(2) The infra-red data, that was available was compared with the results obtained in this work in connection with the influence of the addition of CH_2 in the chain.

(3) Elastic contents of the different linkages have been calculated.

(4) Effects of homology and complexity as well as the effects of isomerism have been studied.

G. R. P.

CHEMISTRY*

I.—*Studies in Silicic Acid Gels.*

By J. B. DESAI, M.Sc. (The Royal Institute of Science, Bombay.)

The problem of the formation of silicic acid gels has been investigated by a study of (1) extinction coefficients and (2) viscosity in the presence of various electrolytes and non-electrolytes of the gels during their formation from solutions of sodium silicate and of either acidic ammonium acetate or acetic acid.

The extinction coefficients have been measured by means of Nutting's photometer used in conjunction with the Higher wavelength Spectrometer. The results obtained have been utilised to calculate the time of setting of the gel-forming mixtures and they show that the mixtures setting in minimum time are either slightly alkaline and neutral, and have a p near about 7. The applicability of Smoluchowski's theory of coagulation of a colloidal solution by electrolytes has been extended to the case of gelatin and it has been found to hold for a certain stage of coalescence. The failure of the theory in the early stage of gelatin has been attributed to the fact that the formation of the colloidal particles and their coagulation are taking place simultaneously and in the final stage to the hydration.

The viscosity of the gel-forming mixtures in the presence of electrolytes and non-electrolytes has been found to increase slowly in the beginning mainly because of an increase in the number of colloidal particles. But the increase in viscosity becomes fairly rapid when the number of colloidal particles in the mixture reaches a limiting value and their aggregation and hydration exert a predominating influence. The alcohols exert an accelerating influence on the rate of increase of viscosity of the alkaline and moderately acidic mixtures while they retard that of the highly acidic ones. The order of the effect of alcohols in both the cases is C_3H_7OH C_2H_5OH CH_3 OH but it is reversed in moderately acidic medium containing only small quantities of the alcohols.

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* The abstracts of the theses of 11 candidates out of the 14 who were awarded the degree of M. Sc. in 1931–1932 are given here. It was not found possible to get the abstracts of the theses of the following three candidates from Baroda College: Messrs R. P. Patel, V. B. Thosar and K. N. Chokshi.

The dehydration of silicic acid gels of the same concentration had different *pH* values has been studied and it is found that the loss of water is least in neutral gels and increases with an increase in the acidity or alkalinity of the gel-forming mixtures. It is suggested that the rate of loss of water depends upon the rate of formation of aggregate and that the amount of water held in the capillaries depends upon the density of change on the colloidal particles originally present in the sol.

M. P.

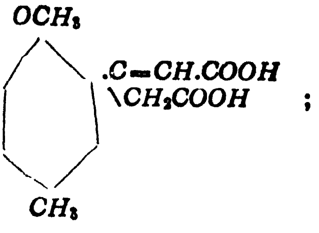
II. Paper by G. R. GOGATE, M. Sc. (The Ranade Industrial and Economic Institute, Poona.)

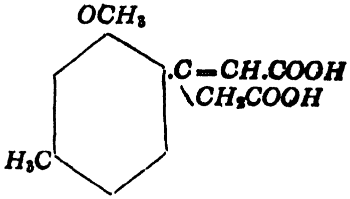
Part I.—Condensation of Acetone-di-carboxylic acid with para and meta cresolmethyl ethers.

Part. II—Oxidation of Embelin by Nitric Acid.

Part I. Condensation of acetone-di-carboxylic acid with para and meta cresolmethyl ethers.

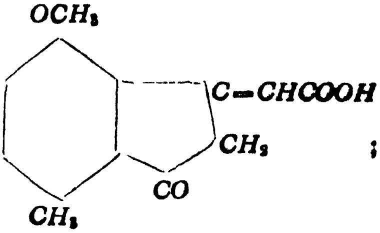
(1) Glutaconic acids, ortho substituted to the methoxyl group of the phenolic ether, have been synthesised by direct condensation.

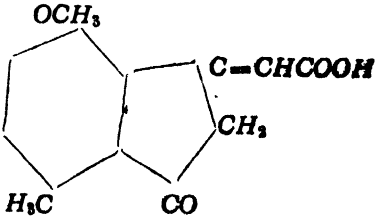




(2) The same glutaconic acids have been synthesised from the corresponding coumarin-4-acetic acids.

(3) Monocarboxylic acids which have been shown to have a hydrindone structure, have been synthesised from these glutaconic acids.





In the case of paracresol methylether, such a monocarboxylic acid is produced even in the original condensation along with the glutaconic acid. Such compounds have not been recorded so far in such condensations.

(4) A monocarboxylic acid of a high melting point—252°C and also a high equivalent—354 has been obtained only in the case of paracresol methylether condensation. Its relation with the corresponding hydrindone monocarboxylic acid has been found out, but its complete structure is under investigation.

(5) The usual derivatives of these glutaconic acids, such as the anhydrides acid esters diesters, decarboxylation products, pyridine derivatives, semianilides and anils have been prepared and studied.

(6) The special derivatives of the anhydrides of these glutaconic acids, with semi carbazide, phenyl hydrazine and acetic anhydride have been prepared and studied.

(7) Some new derivatives of the anhydrides and anils of these glutaconic acids have been synthesised in comparison with those of their pyridine derivatives, *e. g.* isonitroso and benzoyl derivatives.

(8) In all about 70 new compounds have been prepared.

Part II.—Oxidation of Embelin by nitric acid.

(1) Embelin from Embelia Ribes or "Vavadings" has been oxidised by nitric acid of various dilutions.

(2) From among the oxidation product, normal lauric acid, oxalic acid, lauronitrile and lauramide have been definitely isolated and identified.

(3) In the light of these findings, the results of Kaul, Roy, and Dutt, who report the isolation of isolauric acid in the oxidation of Embelin, have been doubted, and those of Hefter and Feuerstein confirmed.

D. B. L.

III.—*Studies in Colloidal Thorium Hydroxide.* By N. V. KAREKAR, M. Sc. (Wilson College, Bombay.)

Part I. Adsorption of the similarly and oppositely charged ions in the presence and absence of non-electrolytes by thorium hydroxide sol dialysed to different extents.

It is found that the greater the valency of the similarly charged ion the greater is its adsorption; adsorption is, however, found to decrease with the progress of dialysis. The adsorption of the coagulating ion in the presence of univalent and bivalent similarly charged ions is found to decrease on the addition of methyl, ethyl and isopropyl alcohols, the lower members of the homologous series being more effective in cutting down the adsorption than the higher members; in the presence of trivalent similarly charged ion, the adsorption of the coagulating ion is found to increase on the addition of non-electrolytes, the adsorption being greater in the presence of lower members of the series than the higher members.

Part II. Determination of the coagulation velocity (photo-electric cell method) of colloidal *thorium hydroxide dialysed to different extents.*

The results obtained with *KCl* $MgCl_2$ and $AlCl_3$ are found to support generally the conclusions arrived at by Patel and Desai (Trans. Faraday Soc., 106, 128, 1928).

Part. III. Measurements of viscosity of colloidal thorium hydroxide dialysed to different extents.

The viscosity of the sol increases with the progress of dialysis. It is found that on the addition of amounts of electrolytes insufficient to bring about coagulation the viscosity of the sol decreases, addition of amounts of larger amounts of electrolyte increasing the viscosity considerably.

B. N. D.

IV. Papers by V. C. PAREKH, M. Sc. (Indian Institute of Science, Bangalore.)

Paper I. Higher fatty acids from Ben Oil.

Paper II. Chemical Composition of Mysore Chrysalis Oil.

Paper III. An attempt to synthesise pp-di-phenylene: A study of the Molecular Complexity of the oxidation product of p-phenylene di-mercaptan.

Paper IV. Formation of Grignard Reagents from Higher Alkyl Iodides.

Paper V. An attempt at an asymmetric synthesis of Sulphur Compounds.

Paper I:—Higher fatty acids from Ben Oil.

Ben oil, occurring in the seeds of Moringa Pterygosperma to the extent of 36·6 per cent., was examined for its constituents and was found to contain

Myristic acid	...	7·3 per cent.
Palmitic acid	...	4·2 ,,
Oleic acid (Δ^{9}:10 type)		65·8 ,,
Stearic acid	...	10·8 ,,
Behenic acid	...	8·9 ,,
and Lignoceric acid	...	3·0 ,,

The unsaponifiable matter, occurring to the extent of 3·7 per cent. in the oil, consisted of 9 per cent. of phytosterol.

The oil is found to be a good source of a Behenic acid in nature.

During the course of this investigation, Behenic acid was synthesised from *n*-cicosanic acid, and also by the hydrogenation of methyl erucate and finally hydrolysing the resulting methyl behenate.

Paper II:—Chemical composition of Mysore Chrysalis Oil.

The chrysalides, supplied by the Sericulture Department of the Mysore Government contained 20·2 per cent. of a semidrying oil, which was examined for its constituents. It contained

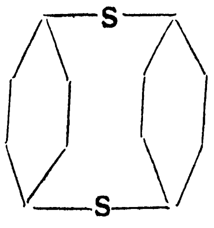
α-Linolenic acid	...	10·5 per cent.
Iso-linoleic acid	...	38·2 ,,
Oleic acide (Δ^{9}:10 type)		33·8 ,,
Palmitic acid	...	13·5 ,,
and Stearic acid	...	4·0 ,,

The unsaponifiable matter occurring to the extent of 3·2 per cent. was found to contain a considerable amount of Cholesterol.

The absence of iso-palmitic acid and the presence of stearic acid in the oil, investigated, are the striking differences from the oils of the Japanese chrysalides.

Paper III :—An attempt to synthesise pp-di-phenylene: A study of the Molecular Complexity of the oxidation product of p-phenylene di-mercaptan.

An attempt has been made to synthesise pp-diphenylene by desulphurisation of $(C_6H_4S_2)_x$ obtained by the oxidation of p-phenylene-di-mercaptan. Various desulphurising reagents such as sodium, molecular sodium, mercury and its salts (chloride and nitrate), natur cupfer as also freshly reduced copper in different media like dry benzene and xylene at high temperature and under pressure have been tried. Of all these reagents freshly reduced copper has been found to be the best and with its aid it has been possible to effect partial desulphurisation of the oxidation product and a compound having the molecular formula $C_{12}H_8S_2$, and a probable structure



has been obtained.

Paper IV :—Formation of Grignard Reagents from Higher alkyl Iodides.

Six higher alkyl Iodides (*viz.*, $C_{12}H_{25}I$, $C_{14}H_{29}I$, $C_{16}H_{33}I$, $C_{18}A_{37}I$, $C_{20}H_{41}I$ and $C_{22}H_{45}I$) were made to react with metallic magnesium, and the yields of the Grignard Reagents so formed were studied, and these were found to be as follows:

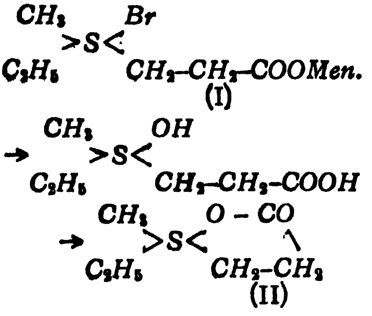
Iodides.		Yield of Grignard Reagents.
Lauryl	...	44 per cent.
Myristyl	...	47 ,,
Palmityl	...	44·2 ,,
Stearyl	...	44·3 ,,
n-Eicosyl	...	43·3 ,,
Behenyl	...	41·1 ,,

The procedure adopted for the separation of Higher Hydrocarbons (*viz.*, $C_{24}H_{50}$, $C_{28}H_{58}$, $C_{32}H_{66}$, $C_{36}H_{74}$, $C_{40}H_{82}$ and $C_{44}H_{90}$) from the Grignard Reagents thus formed, was to hydrolyse the latter, when in the reaction mixture, and to distil under reduced pressure the resulting Hydrocarbons. In the case of the last two, recourse was had to the extreme insolubility of C_{40}-and C_{44}-hydrocarbons in ether, whereas the lower hydrocarbons (*viz.*, $C_{20}H_{42}$ and $C_{22}H_{46}$) were found to be fairly soluble in that solvent on boiling. The proportion of the lower hydrocarbons thus obtained after hydrolysis is taken as the proportion of the Grignard Reagents formed in these reactions.

During the course of this investigation two new hydrocarbons $C_{80}H_{82}$ (m.p., 79°-81°)and $C_{44}H_{90}$ (m.p., 83°-85°) have been synthesised.

Paper V :—An attempt at an Asymmetric synthesis of Sulphur Compounds.

The sulphonium compound (I) obtained by the action of ethyl-methyl-sulphide on menthyl-β-bromo-propionate gave after removal of the menthyl grouping a thetine like compound (II), which was, however, found to be optically inactive.



$$\begin{array}{lcl} CH_3 & & Br \\ & >S< & \\ C_2H_5 & & CH_2{-}CH_2{-}COOMen. \end{array}$$

(I)

$$\rightarrow \begin{array}{lcl} CH_3 & & OH \\ & >S< & \\ C_2H_5 & & CH_2{-}CH_2{-}COOH \end{array}$$

$$\rightarrow \begin{array}{lcl} CH_3 & & O - CO \\ & >S< & \quad \backslash \\ C_2H_5 & & CH_2{-}CH_2 \end{array}$$

(II)

During the course of this investigation two new compounds have been prepared for the first time, *viz.*, β-bromo-propionyl chloride (B.P.45-47°/480-490mm.) and its mentyl ester (B.P. 123-125°/3-4 mm.).

P. C. G.

V.—*Studies in Positive Hydrosols.* By P. M. BARVE. M. Sc. (Wilson College, Bombay)

Part I. Sensitisation of Colloidal thorium hydroxide by non-electrolytes in presence of potassium chloride and magnesium chloride.

The results are found to support the conclusions arrived at by Patel and Desai (*Koll. Zeit.* 318, 1930).

Part II. The effect of dilution and purity of thorium hydroxide hydrosol on coagulation values of different electrolytes.

It was observed that there is stabilisation on dilution in case of chlorides of potassium and magnesium while with the sulphates of these metals there was not much of stabilisation. On comparing the quantities of electrolyte required to coagulate a sol of particular concentration at two different stages of dialysis, it was found that the ratio of these two quantities increases as the sol is diluted more and more in case of potassium chloride and magnesium chloride; in the case of potassium sulphate and magnesium sulphate the ratio, however, decreases as the sol is diluted more and more. Chlorides and sulphates of aluminium give rather abnormal results.

Part III. Measurement of charge on colloidal ferric hydroxide (1) with the progress of dialysis, (2) with dilution and (3) in presence of varying amouts of KCl, $MgCl_2$ and K_2SO_4.

Charge measurements were made with Mukherjee's improved method. Dialysate was found to be suitable as an upper liquid upto a certain stage of the purity of the colloid. The results show that although with the progress of dialysis the charge first increases and then decreases the flocculation value with *KCl* continuously decreases. The cataphoretic speed is found to increase on the addition of small amounts of electrolytes with univalent coagulating ion although with larger amounts of the electrolytes the cataphoretic speed decreases. In the case of bivalent coagulating ion the maxima in the cataphoretic speed—concentration curve is not noticed. The charge on the colloid is found to increase on dilution. The results have been explained from the point of view of (*a*) variation in the surface density of the charge, (*b*) variation in the thickness of the double layer and (*c*) preferential adsorption of the similarly charged ion.

B. N. D.

VI.—*Studies in Thiol Series.*

By C. T. BHATT, M. Sc. (M. R. Science Institute, Gujarat College, Ahmedabad.)

Paper I. Thiol Derivatives of o,m, and p-methoxy-toluenes.

Paper II. Thiol Derivatives of o,m, and p-methoxy-benzoic acids.

Paper III. 4–sulpho–salicylic acid.

Paper IV. 5-sulpho-3-nitro-benzoic acid and 5-sulpho-3-hydroxy-benzoic acid.

Paper V. o-nitro-toluene-6-sulphonic acid and its derivatives.

Paper VI. Methylation of (a) nitro-cresols and (b) nitro and sulpho-hydroxy-benzoic acids by methyl sulphate.

Paper VII. Bromination of methoxy sulphonic acids.

Paper VIII. The reaction between acetylene and sulphur between the temperatures 290°C and 390°C.

Paper I. Thiol Derivatives of o, m, and p-methoxy-toluenes.

Isomeric Thiol derivatives of *o*, *m*, *p*, methoxy toluenes have been synthesised and studied. The methods employed consist in starting with (A) methoxy-toluene-sulphonic acid, (B) nitro-toluene-sulphonic acid, and (C) nitro-cresol.

(A) Methoxy-toluene-sulphonic acid was converted into sulphonyl chloride, which when reduced with tin and hydrochloric acid gave thiol-methoxy-toluene.

(B) Nitro-toluene-sulphonic acid was converted via toluidine and cresolsulphonic acids into methoxy-toluene sulphonic acid. The latter on treatment similar to that in (A) gave thiol-methoxy-toluene.

(C) Nitro-cresol on methylation and subsequent reduction passed into amino-methoxy-toluene. The latter was converted into methoxy-toluene-sulphinic acid by Gattermann's method (Ber. 1899, *32*, 1149). The sulphinic acid on reduction with tin and hydrocholoric acid gave thiol-methoxy-toluene. (Only in the preparation of 6–thiol 2–methoxy toluene, 6–nitro 2–methoxy toluene, obtained by a method described by Simonsen and Nayak (*J. C. S.*, 1915, *107*, 830), was used.

All isomeric methoxy-tolyl-mercaptans passed on methylation into the isomeric methyl-thiols of *o*, *m*, and *p*-methoxy toluenes. These with the exception of 6–methylthiol 2–methoxy toluene on subsequent oxidation with alkaline permanganate produced isomeric methoxy-benzoic-acid methyl-sulphones, which possessed definite crystalline form and sharp melting point,

	DERIVATIVES OF									
	2-Methoxy-toluene				3-Methoxy-toluene				4-Methoxy toluene	
	Position of the groups				Position of the groups				Position of the groups	
Group present	3	4	5	6	2	4	5	6	2	3
Thiol	235°-6°	238°-9°	40° 234°-5°	238°-9°	256°-7°	254°	251°-2°	253°-4°	253°-4°	37° 252°-3°
Methyl thiol ...	254°	255°-6°	259°	256°	269°	259°	262°-3°	272°	260-61°	262°
Methyl sulphone-methoxy-benzoic acid	166°	151°	190°	...	212°	227°	195°	180°	180°	215°
Method employed	C	B	A	C	C	C	C	A	B	A

Paper II.—Thiol Derivatives of o, m, and p-methoxy-benzoic acids.

Attempts to synthesise isomeric thiol derivatives of *o*, *m*, and *p*-methoxy-benzoic acids, from the corresponding sulpho-methoxy-benzoic acids, are described. The latter were prepared, wherever possible, from (*a*) methoxy-benzoic acid on sulphonation, (*b*) sulpho-hydroxy-benzoic acid on methylation, and (*c*) methoxy-toluene-sulphonic acid on oxidation.

The work on 2-thiol-3-methoxy benzoic acid, 6-thiol-and 3-thiol-2-methoxy benzoic acids is kept pending for the present because the corresponding sulpho-methoxy benzoic acids could not be obtained.

The other sulpho-methoxy benzoic acids gave, on trituration with phosphorus pentachloride, the corresponding chloro-sulphonyl methoxy-benzoylchlorides which when left with cold water for partial hydrolysis showed that

(*a*) 4-and 5-chloro-sulphonyl-2-methoxy-benzoylchlorides are readily affected;

(*b*) 5-chloro-sulphonyl-3-methoxy-benzoylchloride and 3-chloro-sulphonyl-4-methoxy-benzoylchloride take a pretty long time for partial hydrolysis, while

(*c*) 6-chloro-sulphonyl—3—methoxy-benzoylchloride and 2-chloro-sulphonyl-4-methoxy-benzoyl-chloride, *i.e.*, the derivatives of *o*-sulpho-benzoic acids, resist action of cold water. On prolonged treatment both chloro-sulphonyl and carbonyl-chloride groups were simultaneously affected. The study of 6-thiol-3-methoxy-benzoic acid and 2-thiol-4-methoxy-benzoic acid is therefore reserved for future investigation.

The chloro-sulphonyl-methoxy-benzoic acids obtained above were reduced by Gattermann's method (Ber. 1899, *32*, 1149), when the thiol-methoxy-benzoic acids were produced. On methylation these passed into the methyl-thiol-methoxy benzoic acids. The latter on oxidation with permanganate yielded methoxy-benzoic acid methyl sulphones, identical with those described in Paper I.

The work described in this and the preceding paper leads to a method for establishing the constitutions of numerous nitro or sulphonic acid-derivatives related to *o*, *m*, and *p*-substituted nitro, sulpho, hydroxy, or methoxy-toluenes or methoxy-benzoic acids.

	DERIVATIVES						OF			
	2. Methoxy benzoic acid				3. Methoxy benzoic acid				4. Methoxy benzoic acid	
	Position of groups				Position of groups				Position of groups	
Group present	3	4	5	6	2	4	5	6	2	3
Thiol m. p.	...	95^0	206^0	...	...	180^0	162^0	...	...	317^0(deco.)
Methyl thiol m. p.	...	112^0	75^0	...	...	193^0	155^0	...	...	205^0
Methyl sulphone m. p.	...	151^0	190^0	...	...	227^0	195^0	...	...	215^0

Paper III.—4-Sulpho-salicylic acid.

4-sulpho-salicylic acid has been synthesised and studied together with its derivatives.

For this purpose a critical study of the products of sulphonation of *o*-nitro-toluene at 120^0 and 150^0 was carried out. o-Nitro-toluene-4-sulphonic acid, which was found to be the only product of the reaction, was then used as the starting material. On oxidation the sulphonic acid passed into 2-nitro-4-sulpho-benzoic acid which on reduction gave 2–amino–4–sulphobenzoic acid. Both the nitro and amino-sulphonic acids were identical with those described by Hart (*Amer. Chem. J. 1*, 352). Treatment with nitrous acid converted the amino-acid into a diazo-compound (decom. 158^0), which when decomposed with boiling water, gave 4-sulpho-salicylic acid in a pure state and in quantitative yield.

4-Sulpho-salicylic acid $C_7H_6O_6S$, $3H_2O$, plates, melts at 79^0 and gives on desiccation a monohydrate, m.p. 148^0. Both the hydrates are deliquescent. The sodium hydrogen salt crystallises in needles with $2H_2O$, potassium and ammonium hydrogen salts separate in prismatic plates. The copper salt is a green powder.

4–Sulpho–2–methoxy–benzoic acid, $C_8H_8O_6S, H_2O$, needles, melts at 152^0 and gives a micro-crystalline barium salt. Treatment with phosphorus pentachloride and subsequent digestion with cold water produced 4-chloro-2-methoxy-benzoic acid, m.p. 149°. The latter gave with ammonia sulphonamido-2-methoxy-benzoic acid, m.p. 201°, identical with that obtained from 2-methoxy—toluene—4–sulphonamide on oxidation. The configuration of 4-sulpho-salicylic acid was proved from fusion experiments as well. The fusion of sulphonic acid, and also its methyl ether, with alkali produced β-resorcylic acid (2:4–dihydroxy–benzoic acid) m.p. 213°. The latter on methylation gave a mixture of 4-methoxy-salicylic acid, m.p. 155°, and 2:4-dimethoxy-benzoic acid, m.p. 108°. Similarly, fusion converted 4-sulphonamido–2–methoxy-benzoic acid into 4-sulphonamido-salicylic acid, m.p. 246°.

4-Sulpho–2–nitro–benzoic acid was converted into 4-chloro-sulphonyl–2–nitro–benzoyl chloride (oil) which when treated with (*a*) water, produced 4-chloro-sulphonyl-2-nitro–benzoic acid, m. p. 204°, and (*b*) ammonia, 4–sulphonamido-2-nitro–benzonamide, m. p. 225°. The former was digested with ammonia and the latter hydrolysed with hydrochloric acid when the same 4-sulphonamido-2-nitro-benzoic acid, m. p. 198°, was obtained. The latter on reduction gave 4-sulphonamido-2-amino-benzoic acid.

(For 4-thiol-2-methoxy-benzoic acid, 4-methyl-thiol-2–methoxy-benzoic acid and 2-methoxy-benzoic acid 4-methyl-sulphone see Paper II).

4-Sulpho-and 4-sulphonamido-2 amino-benzoic acids, 4-sulpho- and 4-sulphonamido--salicylic acids, described above,, show a blue fluorescence in dilute alkaline solutions and give violet colouration with ferric chloride.

Paper IV.—5-Sulpho-3-nitro-benzoic acid and 5-sulpho-3-hydroxy-benzoic acid.

The nitro-sulpho-benzoic acid described by Limpricht and Uslar (*Ann.*, 1858, *106*, *27*), Taverne (*Rec. Trav. Chem.*, 1906, *25*) and S. van Dorssen (ibid. 1910, *14*, 368) is found to be 5-sulpho-3-nitro-benzoic acid, since it gives (*a*) 5–sulpho–3–hydroxy–benzoic acid identical with Hopfgartner's acid (M., *14*, 694), (*b*) 5-sulphonamido-3–methoxy–benzoic acid identical with that obtained from 3–methoxy–toluene–5–sulphonamide and (*c*) 3-methoxy-benzoic acid–5–methyl–sulphone identical with that described in Papers I and II.

The nitro–sulphonic acid, $C_7H_5O_7SN$, H_2O, m.p. 70°, was obtained on sulphonation of benzoic acid followed by nitration. On desiccation the anhyd. acid, m.p. 152°, was obtained. The barium-hydrogen salt crystallises in rectangular plates with $4H_2O$. The sodium-hydrogen and potassium-hydrogen salts crystallise with $\frac{1}{2}H_2O$ and $1H_2O$ respectively. With phosphorus pentachloride it produced 5–chlorosulphonyl–3–nitro-benzoylchloride, m.p. 64°, which gave on treatment with (*a*) water, 5-chlorosulphonyl-3-nitro-benzoic acid, m.p. 70°, (*b*) ammonia, 5–sulphonamido–3–nitro–benzamide, m.p. 226°. The former when digested with ammonia and the latter, with hydrochloric acid, produced the same 5–sulphonamido–3–nitrobenzoic acid, m.p. 230^0. The 5-sulpho-3-nitro-benzoic acid and 5-sulphonamido-3-nitro-benzoic acid were reduced with ammonium sulphide when 5-sulpho-3-amino-benzoic acid, and 5-sulphonamido-3-amino-benzoic acid, m.p. 242^0, were produced.

5-Sulpho-3-amino-benzoic acid was diazotised and the diazo-compound, plates, (decom. 137^0), decomposed by boiling water: 5-sulpho-3-hydroxy-benzoic acid was obtained in a pure state and quantitative yield.

5–Sulpho–3–hydroxy—benzoic acid, $C_7H_6O_6S$ $2H_2O$, needles or plates, softens above 70^0 and shows no sharp melting point. The hydrate gives on desiccation a monohydrate which shrinks at 135^0 and melts at 142^0. The normal potassium salt $3H_2O$ was identical with that described by Hopfgartner.

The sulpho–hydroxy–benzoic acid gave, on methylation, 5-sulpho-3-methoxy-benzoic acid, $C_8H_8O_6S$, $2H_2O$, needles, m.p. 125^0. The latter gives potassium-hydrogen salt with $1H_2O$. The sodium-hydrogen salt presented difficulty in separation.

On trituration with phosphorus pentachloride the sulpho-methoxy-benzoic acid produced a chlorosulphonyl-methoxy-benzoyl–chloride, m.p. 51·5,^{0} which gave on treatment with (*a*) water, 5-chlorosulphonyl-3-methoxy benzoic acid m.p. 160^0, and (*b*) ammonia, 5-sulphonamido–3—methoxy–benzamide, m.p. 184^0. The former when digested with ammonia and latter when hydrolysed with hydrochloric acid yielded the same sulponamido-methoxy-benzoic acid, m.p. 214.^{0} The latter was identical with 5-sulphonamido 3-methoxy-benzoic acid obtained from 3–methoxy–toluene–5–sulphonamide on oxidation.

5—sulpho–3-hydroxy–benzoic acid and its methyl ether were fused with alkali when α-resorcylic acid (3 : 5 dihydroxy-benzoic acid,) m.p. 233^0, was obtained. This proves the constitutions assigned to sulpho-hydroxy-benzoic acid and sulpho-nitro-benzoic acid. α-Resorcylic acid gave on methylation 3 : 5 dimethoxy-benzoic acid, m.p. 176^0.

Paper V. o–Nitro–toluene–6–sulphonic acid and its derivatives.

Attempts in connection with the syntheses of *o*–nitro–toluene–6–sulphonic acid, *o*-cresol-6-sulphonic acid, 6-sulpho-2-nitro-benzoic acid and 6-sulpho-salicylic acid are described.

o–Nitro–toluene—6—sulphonic acid was first prepared. For this purpose, *p*–nitro–toluene–2–sulphonic acid, obtained from *p*-nitrotoluene on sulphonation, was nitrated when 2 : 4 dinitro-toluene-6-sulphonic acid was produced. The dinitro-sulphonic acid gives a barium salt, plates, with $4H_2O$, red coloured sodium and potassium salts, and a straw coloured ammonium salt. The latter on treatment with phosphorus pentachloride gave 6-chlorosulphonyl-2:4-dinitro-toluene, m.p. 107°. (Attempts to prepare the same acid from 2:4-dinitro-toluene on sulphonation were unsuccessful.)

The ammonium 2:4–dinitro–toluene-6-sulphonate, on reduction with ammonium sulphide, produced 2-nitro-4-amino-toluene-6-sulphonic acid in golden yellow needles. The amino-sulphonic acid when diazotised produced a red coloured diazo-compound which exploded violently at 162°. When decomposed with absolute alcohol the latter gave *o*-nitro-toluene-6-sulphonic acid.

The *o*-nitro-toluene-6-sulphonic acid gives red coloured sodium and potassium salts and a straw coloured ammonium salt. The latter gave on treatment with phosphorus pentachloride an oily sulphonyl chloride which when digested with ammonia passed into *o*-nitro-toluene–6–sulphonamide, m. p. 166·5.° The latter was evidently different from other isomeric sulphonamides so far known.

The *o*-nitro-toluene-6-sulphonic acid, on reduction with tin and hydrocholoric acid, gave *o*-toluidine-6-sulphonic acid. The diazotisation of the latter and subsequent conversion into *o*-cresol-6-sulphonic acid presented difficulty and could not be accomplished.

The nitro-sulphonic acid was oxidised with permanganate but in all experiments 6-sulpho-2-nitro-benzoic acid could not be traced. This indicated that the benzene ring was ruptured during oxidation. Further work in connection with 6-sulpho-2–nitro-benzoic acid and 6-sulpho-salicylic acid is under investigation.

Paper VI. Methylation of (a) nitro-cresols and (b) nitro and sulpho-hydroxy-benzoic acids by methyl sulphate.

Methylation by means of dimethyl sulphate according to (*a*) the usual procedure in aqueous alkaline solutions and (*b*) a special method described by Haworth and Lapworth (*J.C.S.*, 1923, *123*, 2968) has been tried on 5-nitrocresol, 2–nitro-*p*-cresol, 3-and 5-nitro-salicylic acids and 3-and 4-sulpho-salicylic acids.

The results show that

(i) the usual procedure fails in all cases except 4-sulpho-salicylic acid;

(ii) Haworth and Lapworth's method is applicable in the methylation of 5-nitro-*o*-cresol, 2-nitro-*p*-cresol and 3-nitro-salicylic acid,

while (iii) 5-nitro-salicylic acid and 3–sulpho-salicylic acid cannot be methylated by both the methods.

Paper VII. Bromination of methoxy-sulphonic acids.

The methoxy-toluene-sulphonic acids described in Paper I and the sulpho-methoxy-benzoic acids described in Papers II, III and IV were brominated according to the method of Meldrum and Shah (*J. C. S.*, 1923, *129*, 1982). It was found that only in the case of 3-methoxy-toluene-6-sulphonic acid and 6-sulpho-3-methoxy-benzoic acid, where the sulphonic acid group is in para position to the methoxy group, bromination displaced the sulphonic acid group producing 6-bromo-3-methoxy-toluene, b. p. 236^{0}-37^{0}, and 6-bromo-3-methoxy benzoic acid, m. p. 164^{0}, respectively. This is in agreement with the observations of Meldrum and Shah. *m*-tolyl-methylether and *m*-methoxy-benzoic acid, when brominated in acetic acid solution, produced substances identical with those obtained from the *p*-methoxy-sulphonic acids given above.

Paper VIII. The reaction between acetylene and sulphur between the temperatures 290⁰ and 390⁰.

The reaction products of acetylene and sulphur between the temperatures 290^{0} and 390^{0} were studied.

The following gaseous, liquid and solid products were obtained:—

Gaseous :—Hydrogen sulphide, thiophene, and thiophenol.
Liquid :—Carbon-disulphide, thiophene and thiophenol.
Solid :—Carbon.

Thiophenol is not obtained by any previous workers. The methods followed for separating the products are described.

M. S. S.

VII.—***Condensation of Chloral with 2-hydroxy-p-toluic acid and its methyl-ether.*** By B. M. KAPADIA, M. Sc. (The Royal Institute of Science, Bombay.)

The author has obtained the acetic acid derivatives of 2-hydroxy-p-toluic acid and its methylether.

The main reactions are (A) condensation of chloral with (1) $C_6H_3.\overset{1}{CH_3}.\overset{2}{OH}.\overset{4}{COOH}$ and (2) $C_6H_3.\ \overset{1}{CH_3}\overset{2}{OCH_3}.\ \overset{4}{COOH}$.; so as to get (3) $C_6H_2.\overset{1}{CH_3}\overset{2}{OH}\ \underbrace{\overset{3}{(CHCCl_3)}.\ \overset{4}{CO}}_{o}$ m.p. 232^{0} and (4) $C_6H_2.CH_3.OCH_3.\underbrace{CO.\ (CHCCl_3)}_{o}$ m.p. 132^{0}. (B) Reduction of condensation product with zinc and acetic acid, so as to get (5) $C_6H_2.\overset{1}{CH_3}.\overset{2}{OH}.\ \overset{3}{(CH_2CHCl_2)}\ \overset{4}{COOH}.$ m.p. 184^{0} and (6) $C_6H_2.\overset{1}{CH_3}\ \overset{2}{OCH_3}.\overset{4}{COOH}.\ \overset{5}{(CH_2.CHCl_2)}$ m.p. 195^{0}. (C) Simultaneous hydrolysis and oxidation of the reduction product with sulphuric acid (conc.); the reaction converted compound (5) into (7) $C_6H_2.\overset{1}{CH_3}.\overset{2}{OH}\ \overset{3}{(CH_2COOH)}.\ \overset{4}{COOH}$ m.p. 213^{0} and compound (6) into (8) $C_6H_2.\overset{1}{CH_3}.\overset{2}{OH}.\overset{4}{COOH}.\ \overset{5}{(CH_2.COOH)}$ m.p. 209^{0}. (Note that OCH_3 group is simultaneously hydrolysed and the compound (7) and (8) are different which is further proved by the m.p. of their mixture which is 200^{0} and also as follows ;—

Compound (7) was further condensed with chloral when (9) $C_6H.\overset{1}{CH_3}.\overset{2}{OH}.(\overset{3}{CH_2.COOH}).\underset{[O]}{\overset{4}{CO}.\overset{5}{CH}}$ CCl_3 m.p. 249^0 was obtained, while compound (8) gave quite remarkably (10) $C_6H_3.\overset{1}{CH_3}.\overset{2}{OH}.\overset{4}{COOH}.\overset{5}{CH_3}$ m.p. 170^0–171^0 Compound (9) was reduced to get (11) $C_6H.\overset{1}{CH_3}.\overset{2}{OH}.(\overset{3}{CH_2}.COOH)\,\overset{4}{COOH}.\overset{5}{(CH_2.CHCl_2)}$ m.p. 202^0–205^0 Hydrolysis & oxidation with H_2SO_4 (12) $C_6H.\overset{1}{CH_3}.\overset{2}{OH}.(\overset{3}{CH_2}.COOH).\overset{4}{COOH}.\overset{5}{(CH_2COOH)}$ m.p. 220^0.

The action of sodium hydroxide solution on compound (3) gave (13) $C_6H_2.\overset{1}{CH_3}.\overset{2}{OH}.\overset{3}{[CH.(OH).COOH]}.\overset{4}{COOH}$ m.p. 115^0 and on (9) gave (14) $C_6H.\overset{1}{CH_3}.\overset{2}{OH}.(\overset{3}{CH_2}COOH).\overset{4}{COOH}.[CH(OH).COOH]$ m.p. 246^0 but the methyl ether compound (4) gave (15) $C_6H_2.\overset{1}{CH_3}.\overset{2}{OCH_3}.\underset{[O]}{\overset{4}{CO}.\overset{5}{CH}}\,COOH$ m.p. 222^0.

Acetaldehyde derivatives were produced by the action of alkali on the reduction compounds (5) and (6). The result is unconfirmed.

It should be noted here that the $-OH$ group directs the condensation in orthoposition while the $-OCH_3$ group directs it in the para position alone.

N. W. H.

VIII.—(*i*) *Chemical Composition of the essential oil from Curcuma Longa, Linn (Turmeric oil),* (*ii*) *Formation of Curcumone from turmerol and* (*iii*) *Constituents of the volatile oil from Acorus Calamus, Linn* (*Sweet-flag*). By N. C. KELKAR, M.Sc. (Indian Institute of Science, Bangalore).

(*i*) *Examination of Turmeric Oil.*

Turmeric oil examined was obtained by distilling in steam turmeric grown in the Chittoor district of the Madras Presidency. The yield of the oil obtained was 5·8 per cent.

Even though turmeric oil was examined several times since 1868, its chemical composition was still not perfectly known. The only constituents recorded in literature were *d*-*a*-phellandrene and an alcohol called turmerol of formula $C_{13}H_{18}O$ or $C_{14}H_{20}O$.

As a result of a systematic examination of the oil, a number of new constituents have been discovered.

The oil did not contain any phenols, aldehydes or ketones. Caproic acid $C_6H_{12}O_2$ (0·1%) was found to be present as free acid while valeric $C_5H_{10}O_2$ (0·1%) as a combined acid. The oil was distilled at 20 m.m. into various fractions ranging between 70^0 to 180^0C. The lower fractions contained *d*-sabinene $C_{10}H_{16}$ (2·0%), d-α-phellandrene $C_{10}H_{16}$ (4·0%), cineol $C_{10}H_{18}O$ (3·0%) and *d*-Borneol $C_{10}H_{17}OH$ (2·5%). The middle fractions were sesquiterpene hydrocarbons mainly zingiberene $C_{15}H_{24}$ (30·5%) while the higher fractions were mixtures of the sesquiterpene hydrocarbon and sesquiterpene alcohol $C_{15}H_{26}O$ (50·5%).

Considerable changes in optical rotations in the fractions of the whole oil were observed from time to time and this phenomenon is under further investigation.

(ii) Formation of Curcumone from Turmerol.

Earlier investigators made attempts to isolate the alcoholic body from turmeric oil and assigned to the alcohol called turmerol a formula $C_{13}H_{18}O$ or $C_{14}H_{20}O$.

In the present investigation, a sesquiterpene alcohol $C_{15}H_{26}O$ has been isolated and purified by the following methods: (1) By prolonged fractional distillation. (2) By regenerating the alcohol from its boric ester and (3) By re-obtaining the alcohol from its benzoyl ester. The pure alcohol has the following constants: Boiling Point 163-4°/11 mm., $d\,\frac{30^0}{30^0} = 0{\cdot}9506$; and $n_D^{30} = 1{\cdot}5151$.

From the experimental data it is shown that turmerol is a monocyclic tertiary sesquiterpene alcohol of formula $C_{15}H_{26}O$. The body to which formula $C_{13}H_{18}O$ or $C_{14}H_{20}O$ was assigned might have been a mixture of the alcohol $C_{15}H_{26}O$ and the hydrocarbon $C_{15}H_{24}$.

Rupe in 1909 found that the fraction 158°-162°/11 m. m. on treatment with alkali yielded a ketone-curcumone $C_{13}H_{18}O$ which formula was later modified by him as $C_{12}H_{16}O$. Its structure as 2-methyl-2-*p*-tolyl-methyl ethyl ketone $CH_3.\,C_6H_4.\,CH\,(CH_3).\,CH_2.\,CO.\,CH_3$ was finally confirmed by Rupe's synthesis in 1924.

It has been shown that the original oil does not contain the ketone but it is formed by the action of alkali on the alcoholic constituent "turmerol" $C_{15}H_{26}O$.

Turmerol on dehydrogenation with sulphur and selenium gave neither cadalin nor eudalin.

During catalytic reduction with platinum black and hydrogen turmerol was converted into a saturated alcohol $C_{15}H_{30}O$ showing the presence of two double bonds.

The alcohol on oxidation with dilute nitric acid yielded *p*-toluic, terephthalic and oxalic acids.

On oxidation with aqueous $KMnO_4$ as well as with powdered $KMnO_4$ in acetone solution, turmerol gave an acid of melting point 42°-43°C, equivalent 178 and molecular formula $C_{11}H_{14}O_2$, perhaps identical with the acid obtained by Rupe by oxidation of curcumone. Curcumic acid $C_{11}H_{14}O_2$ melting at 42°-43° has the structural formula as *p*-methyl-β-methylhydrocinnamic acid $CH_3.\,C_6H_4.\,CH\,(CH_3).\,CH_2.\,COOH$.

Further work to elucidate the constitution of the alcohol is in progress.

(*iii*) *Chemical composition of the volatile oil from Acorus Calamus* (*sweet-flag*).

The oil examined was obtained by steam distilling the rhizomes of Acorus Calamus grown in Mysore, in 2·7 per cent. yield.

This oil has been known for a long time for its antiseptic properties. The analytical constants of the Mysore sample indicated that these did not fall within the limits of the known commercial oils, this being particularly true of density and refractive index.

The oil mainly consists of asarone $C_{12}H_{16}O_3$ (82%), estimated (1) by conversion into parasarone $(C_{12}H_{16}O_3)_3$ and weighing the latter and (2) by methoxyl determination. It was not found possible to obtain pure asarone by distillation alone. On fractionation at reduced pressure, the lowest boiling fraction consisted of α-pinene $C_{10}H_{16}$ (0·2 %) and asaryl aldehyde $C_{10}H_{12}O_4$ (0·1%). The other constituents were the sesquiterpene calamene $C_{15}H_{24}$ (2·3 %); Eugenol $C_{10}H_{12}O_2$ (0·3%); Methyl Eugenol $C_{11}H_{14}O_2$ (1·2%); Calamenenol $C_{15}H_{24}O$ (5·3 %) and Calameone $C_{13}H_{26}O_2$ (2·2 %). Palmitic $(C_{16}H_{32}O_2)$ and heptylic ($C_7H_{14}O_2$) acids (1·2 %) were detected in the free state while the former was also found in the combined condition along with a small quantity of butyric acid.

P. C. G.

IX.—*Studies in mercuration.*

By V. V. NADKARNI, M. Sc.
(St. Xavier's College, Bombay.)

Studies in Mercuration.

A. Dimroth (Ber. 1898, 31, 2154) proposed that the action of mercuric acetate on the aromatic compounds to form the mercuriorgano derivatives was analogous to the action of water on mercuric salts. This view favourably received by the subsequent workers is questioned in this paper. It is found that

(1) The presence of an alkali accelerates the process of mercuration.

(*a*) Even the addition of small quantity of alkali reduces the time taken for mercuration to a few minutes. A comparative study with and without the addition of alkali. The experiment was tried in the mercuration of 24 substances belonging to different types.

(*b*) Extension of previous work and confirmation of results. The addition of alkali in large quantities produces the anhydride of the hydroxy-mercury derivatives.

(2) Mercuric chloride and mercuric bromide act as general mercurating agents when in presence of alkali 33 different substances were mercurated and the experiment repeated with different alkalies.

(3) Moist mercuric oxide previously used to mercurate pthalein and derivatives has been found to be a general mercurating agent. Eight substances containing different radicals OH, NO_2,

$COOH$, and SO_3H were mercurated.

(4) The use of Mercuric acetamide so far used to mercurate compounds containing a reactive-CH_2-group has been extended to simple aromatic compounds like phenol, cresol etc. 5 different compounds have been mercurated.

(5) Mercuric sulphate acts as a general mercurating agent (24 different substances were mercurated). It was found a more efficient mercurating agent than mercuric acetate.

(*a*) The reaction is quicker.

(*b*) The products obtained are purer.

B. The use of the Grignard reagent in the preparation of metallo-organic compounds.

F. J. S.

X.—*Raman Scattering of Light.*

By GAJANAN VITHAL NEVGI, M. Sc. (Indian Institute of Science, Bangalore.)

The Raman scattering of light has been investigated in the following three different types of isomerism in organic compounds, by using an all-metal quartz spectragraph and a quartz mercury vapour lamp of Heraus type of C. P. 3000.

(i) The butyl, amyl and octyl alcohols have been studied primarily to trace the changes in the Raman Spectra in Primary, Secondary and Tertiary alcohols. Noticeable changes have been observed so as to distinguish between these alcohols.

(ii) Thirteen derivatives of cyclohexane have been studied for their Raman Spectra. Generally all these compounds show similarity in their spectra to aliphatic compounds. The effect of ortho, meta and para type of isomerism on the spectra is mostly observed in the smaller shifts corresponding to long wave length region.

(iii) Eight optically active compounds, all having a formula of $C_{10}H_{16}$ and belonging to the Terpene series have been examined for their Raman Spectra. The Spectra of dextro and laevo rotatory forms of the same compound are exactly identical, but the structural changes among other isomers are shown in smaller shifts.

In every compound several frequencies have been identified with definite chemical bonds.

G. V. N.

XI.—Paper by S. D. SUNAWALA, M. Sc. (Indian Institute of Science, Bangalore.)

Estimation of small amounts of Acetone in pure Methyl and Ethyl Alcohols.—Messinger's method for the estimation of acetone was found unsatisfactory in presence of methyl alcohol, although the conditions suggested by Goodwin (*J.A.C. S.*, 42, 1920, 39–45) were observed. It was found that sodium hypoiodite oxidised methyl alcohol to formic acid and that the rate of this reaction diminished with time, owing to the simultaneous oxidation of the hypoiodite to iodate.

The method suggested by Scott-Wilson (*J. Biol. Chem.*, 1913, *76*, 281) namely precipitation with mercuric cyanide was found to give quantitative results for small amounts of acetone, both in methyl and in ethyl alcohol solutions. Amounts of acetone as small as 0·1 mg. in 100 c.c. of the solution could easily be detected.

A note on the Estimation of Formic Acid in commercial Acetate of Lime.—The accuracy of various methods of estimating formic acid, in presence of acetic acid, were tested, and were then employed in estimating the same in acetate of lime. It was found that the gravimetric method, consisting in the precipitation of mercurous chloride, was preferable and more suitable.

Estimation of Chlorine in Chlorinated Water supplies.—Estimation of chlorine in water in such small amounts as 0·1 to 1 part per million was done by the o-tolidine reagent colorimetrically. The method was tested under different conditions in order to study various sources of error.

Estimation of Potassium by the Cobaltnitrite Method.–This method was found to yield good results only when the relative concentrations of the reactants lie within narrow limits. The precipitates obtained under varying conditions were completely analysed, and the conditions suitable for obtaining $K_2NaCo(No_2)_6.H_2O$ in a pure state were studied. The data obtained enable the determination to be made within an accuracy of about 1 per cent. even in presence of other salts such as those of sodium, calcium, magnesium, etc.

S. D. S.

Table showing the number of M. Sc. Graduates in different branches of Chemistry from 1916 to 1932

Year	Organic	Inorganic	Physical	Biochemical	Total
1916	1	0	1	1	3
1917	0	0	0	0	0
1918	0	0	0	1	1
1919	1	0	0	0	1
1920	2	0	0	3	5
1921	1	1	0	3	5
1922	2	0	0	0	2
1923	3	3	0	0	6
1924	4	0	2	4	10
1925	5	0	3	1	9
1926	10	2	1	1	14
1927	6	0	3	4	13
1928	5	0	2	2	9
1929	9	0	6	4	19
1930	16	0	6	3	25
1931	9	3	9	4	25
1932	5	1	1	0	7
	79	10	34	31	154

Table showing M. Sc. graduates in Chemistry from 1916 to 1932, with the titles of their theses, etc.

Name of the Candidate	Subject of the Thesis	Name of the Professor under whom the candidate worked	Name of the Referee	Remarks
1916				
LAKHUMALANI, J. V.	I. *The Replacement of Sulphonic Acid Groups in Amino-Sulphonic Acid by Halogens.* II. *The Determination of Iodine Values of Oils and Fats by Winkler's Method.*	Dr. J. J. SUDBOROUGH	Dr. J. L. SIMONSEN	Distinction
MULANI, H. M.	*Studies in the Hydrolysis of Phenolic Esters.*	Dr. H. E. WATSON	...	Pass
WAD, Y. D.	*Biological Chemistry and Chemistry of Foods.*	Dr. H. H. MANN	...	Pass
1918				
TAMHANE, V. A.	*Chemical Studies on Safflower Seed and its Germination.*	Dr. H. H. MANN	Dr. GILBERT J. FOWLER	Distinction (Moos Medal)
1919				
BHAGWAT, V. K.	I. *Alcoholysis in the absence of a Catalyst.* II. *Enolic Change in Aldehydes.*	Dr. J. J. SUDBOROUGH	Dr. A. N. MELDRUM	Distinction (Moos Medal)
1920				
ALIMCHANDANI, R. L.	I. *Derivatives of Gallic Acid. Synthesis of 3 : 5 dimethoxy-4-hydroxy-o-phthalic Acid.* II. *Condensation of Chloral with Gallic and Cresotic Acids.*	Dr. A. N. MELDRUM	Dr. J. J. SUDBOROUGH (Bangalore)	Pass

Name of the Candidate	Subject of the Thesis	Name of the Professor under whom the candidate worked	Name of the Referee	Remarks
EDAL-BEHRAM, J. D.	(1) *Some Enzymes of the Leaf of Lantana Camara.* (2) *A Biochemical Study of the Progressive Maturing of the Mowra Flower and the Function of Latex in the Mowra Tree.*	Dr. GILBERT J. FOWLER	Dr. H. H. MANN	Pass
JOSHI, G. V.	*Studies on Fermentation of Cellulose, Part I (under anaerobic conditions)*	Dr. GILBERT J. FOWLER	Mr. C. M. HUTCHINSON (Pusa)	Pass
JOSHI, N. V.	*Studies on the Root Nodule Organism of the Leguminous Plants.*	... ...	Dr. GILBERT J. FOWLER	Pass
MEHTA, MANECKBAI M. (Miss)	*Deterioration of Paper in India*	Dr. J. J. SUDBOROUGH	Prof. G. B. KOLHATKAR	Pass
1921				
SEN, D. L.	*Biochemical Studies in Starch.*	Dr. GILBERT J. FOWLER	M. D. CLOUSTON, Esq. (Director of Ag., Nagpur)	Distinction (Moos Medal)
DESHPANDE, H. B.	*The Manufacture of Artificial Stone and Cements from Dolomite and Hydrochloric Acid.*	Dr. A. R. NORMAND	...	Pass (He appeared for a written examination.)
GANGOLLI, D. M.	*Studies in the Purification of Casein.*	Dr. A. N. MELDRUM	Dr. GILBERT J. FOWLER	Pass
JOSHI, B. M.	*Chemical Study of Heat Rot or Black Heart of Potato.*	Dr. H. H. MANN	M. D. CLOUSTON, Esq. (Director of Ag., Nagpur)	Pass

SAHASRABUDHE, D. L.	*Chemical and Biochemical Study of Soils in connection with the improvement of the deteriorated Cardamum Plants.*	Self.	Dr. J. SEN (Pusa)	Pass
1922				
KARVE, D. D.	*The Interaction of Acids and Esters, Parts I and II.*	Dr. J. J. SUDBOROUGH	Dr. J. L. SIMONSEN (Dehra Dun)	Distinction (Moos Medal)
ATHAVALE, D. Y.	*The Relation between Iodine Values and Refractive Indices of Different Oils during the Progress of Hydrogenation and the Study of Nickel as a Catalytic Metal for Hydrogenation.*	Dr. J. J. SUDBOROUGH	Prof. G. B. KOLHATKAR	Pass
1923				
SHAH, M. S.	*I. Constitution of Sulpho-salisylic Acid.* *II. Synthesis of 5-Hydroxy 2-methoxy Benzoic Acid.* *III. Action of Bromine on para-Hydroxy and para-Methoxy Sulphonic Acids.*	Dr. A. N. MELDRUM	Dr. M. O. FORSTER (Bangalore)	Distinction (Moos Medal)
ADHIKARI, G. M.	*Some Experiments on the Utilisation of Indian Barytes.*	... ...	Dr. E. R. WATSON (Cawnpore)	Pass
AVASARE, M. D.	*Absorption of Halogens by Mercurous Salts, Part I. Formation and Properties of some Complex Compounds of Mercury.*	Dr. K. G. NAIK	Sir P. C. RAY (Calcutta)	Pass

Name of the Candidate	Subject of the Thesis	Name of the Professor under whom the candidate worked	Name of the Referee	Remarks
ENTI, D. R.	*I. Effect of Basic Lead Acetate on Sugar.* *II. Isolation and Identification of various Saccharomycetes Species associated with Mahua Flowers.*	Wilson College, and Department of Agriculture, Mandalay.	Dr. GILBERT J. FOWLER (Bangalore)	Pass
GHADIALI, M. H.	*The Reaction between Cupric Ions and Iodide Ions.*	Dr. A. N. MELDRUM	Prof. J. C. GHOSH (Dacca)	Pass
SHETH, K. M.	*Caffeine Extraction.*	Dr. H. E. WATSON	Dr. H. H. MANN	Pass
1924				
ASUNDI, R. K.	*Boiling Points of Solutions in Methyl Alcohol under Reduced Pressure.*	Dr. A. R. NORMAND	Dr. H. E. WATSON (Bangalore)	Distinction
MALANDKAR, M. A.	*(1) Gum Enzymes.* *(2) Gum of Boswellia Serrata.*	Dr. GILBERT J. FOWLER	Dr. H. H. MANN	Distinction
ADVANI, G. D.	*Velocity of Chemical Change in the Polymethylene Monocarboxylic Acids*	Dr. J. J. SUDBOROUGH & Dr. H. E. WATSON	Dr. J. L. SIMONSEN	Pass
BHATT, D. M.	*Chloralides derived from Hydroxy-Carboxylic Acids.*	Dr. A. N. MELDRUM	Dr. J. J. SUDBOROUGH	Pass
CHRISTIE, RUTH K. (Miss)	*Biochemical Studies relating to the Symbiosis of Seeds and Bacteria.*	Dr. GILBERT J. FOWLER	Major H. W. ACTON, I.M.S. (Calcutta)	Pass
DINANATH, T.	*Biogenesis of the Mohua Oil.*	Prof. GILBERT J. FOWER	Dr. H. H. MANN	Pass
GOKHALE, S. K.	*The Conversion of Eugenol into iso-eugenol and some Experiments on their Oxidation to Vanillin.*	Dr. J. J. SUDBOROUGH	Dr. A. N. MELDRUM	Pass

PATEL, C. S.	*Investigations on the Interaction of Sulphur Monochloride with Organic Acid Amides.*	Dr. K. G. NAIK	Dr. J. J. SUDBOROUGH	Pas
PATWARDHAN, V. G.	*I. Studies in the Chemistry of Sugars in the Juices of Palms, etc.* *II. Studies in the Chemistry of Sugars in the Fruits, specially Mango during ripening.*	Dr. H. H. MANN	Dr. GILBERT J. FOWLER	Pas
VAIDYA, B. K.	*Ferric Hydroxide Sols.*	Dr. A. R. NORMAND	Prof. J. C. GHOSH (Dacca)	Pas
1925				
SHAH, R. C.	*Finely Divided Copper as a Catalyst in bringing about Organic Condensation Reactions in which one or more Halogen Atoms are replaced by other groups.*	Dr. J. J. SUDBOROUGH	Dr. B. B. DEY (Madras)	Dis (M
BHOJRAJ, M. G.	*The Properties of the Group* $CH(OH)CCl_3$.	Dr. A. N. MELDRUM	Dr. M. O. FORSTER (Bangalore)	Pas
DAMLE, N. R.	*The Composition of Rape Oil.*	Dr. J. J. SUDBOROUGH	Dr. E. R. WATSON (Cawnpore)	Pas
KULKARNI-JATKAR, S.K.	*Catalytic Preparation of Ether.*	Dr. H. E. WATSON	Dr. N. R. DHAR (Allahabad)	Pas
WILLIAMS, M. A. S.	*I. A Study of the Behaviour of some strong Electrolytes in Methyl Alcohol under reduced pressure at* 25^0*C.* *II. A Study of the Behaviour of some Organic Crystalline Substances in Methyl Alcohol under reduced pressure.*	... ...	Dr. J. N. MUKERJI (Calcutta)	Pas

Name of the Candidate	Subject of the Thesis	Name of the Professor under whom the candidate worked	Name of the Referee	Remarks
MANKODI, C. L.	*Hydrolysis of Ammonium Salts of weak Acids.*	Dr. C. J. J. FOX	Dr. H. E. WATSON (Bangalore)	Pass
MIRCHANDANI, T. J.	I. *Chemical Investigation of Jamba Seeds, Sind.* II. *Poppy Seed Oil.*	Dr. J. J. SUDBOROUGH	Dr. E. R. WATSON (Cawnpore)	Pass
PATEL, C. K.	*Studies in the Chemistry of Oils and Fats:* *(a) Cashew Kernel Oil.* *(b) Rayan Oil.* *(c) The Use of Mixed Catalysts in the Hydrogenation of Oils.* *(d) Khakan Fat.*	Dr. J. J. SUDBOROUGH	Dr. E. R. WATSON (Cawnpore)	Pass
REGE, R. D.	*Industrial Wastes as Manures.*	Dr. GILBERT J. FOWLER	Dr. W. H. HARRISON (Pusa)	Pass
1926				
DESAI, R. D.	*(1) Iodine as a Catalyst in Reactions involving Elimination of Hydrogen Chloride.* *(2) Relation between Physical Properties and Chemical Constitution of Organic Compounds.* *(3) The Chemistry of Karanja Oil.*	Dr J. J. SUDBOROUGH	Dr. K. G. NAIK	Distinction (R. R. Desai Gold Medal).
HIRWE, N. W.	*Derivatives of Salicylic Acid.*	Dr. A. N. MELDRUM	Dr. M. O. FORSTER (Bangalore)	Distinction

JADHAV, G. V.	*Investigations on the Interaction of Sulphur Dichloride with Substances containing the Reactive Methylene Group.*	Dr. K. G. NAIK	Sir P. C. RAY (Calcutta).	Distinction
NARGUND, K. S.	*Reactions of Chromates at high temperatures.*	Dr. H. E. WATSON	Dr. H. K. SEN (Calcutta)	Distinction
SHAH, M. L.	*Investigations on the Interaction of Sulphuryl Chloride with Substances containing the Reactive Methylene* CH_2*-Group or Substituted Methylene Group.*	Dr. K. G. NAIK	Sir P. C. RAY (Calcutta)	Distinction
BAMJI, C. N.	*Sulpho m. Cresotic Acid and some further Compounds.*	Dr. A. N. MELDRUM	Dr. M. O. FORSTER (Bangalore)	Pass
BHAT, Y. N.	*Interaction of Sulphur Monochloride with Substances containing the Reactive Methylene Group or substituted Methylene Group.*	Dr. K. G. NAIK	Sir P. C. RAY (Calcutta)	Pass
BHATT, L. A.	*I. Reduction of Alkaline earth Sulphates at high temperatures.* *II. Modified Method of estimating Nitric Nitrogen.*	Dr. H. E. WATSON	Dr. H. K. SEN (Calcutta)	Pass
BHIDE, B. V.	*I. Relation between Chemical Constitution of the Acid and its Rate of Esterification.* *II. Velocity of Esterification in Mixed Solvents.*	Dr. J. J. SUDBOROUGH	Dr. A. N. MELDRUM	Pass
DATAR, A. S.	*The Reduction of CHOH.* CCl_3 *Group*	Dr. A. N. MELDRUM	Dr. M. O. FORSTER	Pass

Name of the Candidates	Subject of the Thesis	Name of the Professor under whom the candidate worked	Name of the Referee	Remarks
DESAI, B. N.	*Studies in Positive Hydrosol.*	Dr. A. R. NORMAND	Dr. S. S. BHATNAGAR (Lahore)	Pass
GODE, R. B.	*A Chemical Study of Indian Buffalo-milk Casein.*	Prof. D L. SAHASRABUDHE	Dr. H. H. MANN (Poona)	Pass
KUMANA, S. E.	*Physico-Chemical Studies in Solution of Boric Acid etc.*	Dr. C. J. J. FOX	Dr. H. E. WATSON	Pass
MULANY, M. M.	*I. Studies in the Hydrolysis of Phenolic Esters.* *II. Action of Basic Lead Acetate on Levulose and Glucose.*	Dr. J. J. SUDBOROUGH & Dr. H. E. WATSON	Dr. A. N. MELDRUM	Pass
1927				
BHAGWAT, M. B.	*The Constitution of the Acid formed by the Action of Concentrated Sulphuric Acid on Camphor Quinone.*	Prof. J. L. SIMONSEN	Dr. A. N. MELDRUM	Distinction (Moos Medal)
DEODHAR, G. W.	*Preparation and Properties of Chloral and Bromal Ammonia Derivatives.*	Dr. A. N. MELDRUM	Dr. J. L. SIMONSEN	Distinction
PATWARDHAN, V. N.	*Studies on Amylase from Cholam (Sorghum Vulgare).*	Prof. R. V. NORRIS	The Rev. CAIUS, S. J.	Distinction
THAKUR, A K.	*A Biochemical Study of some Soil Fungi with special reference to Ammonia Production.*	Prof. R. V. NORRIS	Dr. H. H. MANN	Distinction
BUHARIWALLA, N. A.	*Chlorophyll from Indian Plants.*	Prof. R. H. DASTUR	Dr. H. H. MANN	Pass

DIGHE, S. G.	*Viscosity from Strong Electrolytes and their Hydration.*	Dr. A. R. NORMAND	Prof. G. B. KOLHATKAR	Pass
DIKSHIT, V. V.	*Derivatives of p- and o-Cresotic Acids.*	Dr. A. N. MELDRUM	Sir P. C. RAY (Calcutta)	Pass
GHANEKAR, R. V.	*The Chemistry of three Fixed Oils.*	Prof. J. L. SIMONSEN	Dr. H. K. SEN (Calcutta)	Pass
HURRY, N. L.	*Derivatives of Hydroxy Benzoic Acids*	Dr. A. N. MELDRUM	Dr. M. O. FORSTER (Bangalore)	Pass
KHALAP, V. S.	*Studies in Diphasic Systems.*	Prof. C. L. MANKODI	Dr. N. R. DHAR (Allahabad)	Pass
MUDBIDRI, S. M.	*1. Redwood Seed Oil. 2. The Effects of Reduction on the Castor Oil at different temperatures with different Catalysts. 3. Experiments on the Constitution of Lignoceric Acid.*	Prof. J. L. SIMONSEN	Dr. H. K. SEN (Calcutta)	Pass
MUTHANA, M. C.	*Studies in Positive Hydrosol.*	Dr. A. R. NORMAND	Dr. S. S. BHATNAGAR (Lahore)	Pass
SHUKLA, P. P.	*Studies in the Camphane Series.*	Dr. M. O. FORSTER	Dr. K. G. NAIK	Pass
1928				
JOGLEKAR, R. B.	*Preparations and Properties of Synthetic Pure Triglycerides of Saturated Fatty Acids with even number of Carbon Atoms.*	Dr. H. E. WATSON	Dr. P. C. MITTER (Calcutta)	Distin
MENON, K. N.	*(1) Some Reactions of Carone.* *(2) 4-bromo and 4-nitro naphtha-quinaldine.* *(3) The Stereochemistry of Diphenyl Derivatives.* *(4) Chemistry of Cyclopropane ring.*	Dr. H. E. WATSON	Dr. B. B. DEY (Madras)	Distin ion

Name of the Candidates	Subject of the Thesis	Name of the Professor under whom the candidate worked	Name of the Referee	Remarks
SHAH, C. H.	*Investigations on the Interaction of Chlorosulphonic Acid with Substances containing the Reactive Methylene -CH_2- Group, or Substituted Methylene Group together with a Study of Nitration of the Resulting Products.*	Dr. K. G. NAIK	Dr. SHRI KRISHNA (Lahore)	Distinction
TRIVEDI, R. K.	*Investigation on the Interaction of Selenium-tetra-chloride with Substances containing the Reactive Methylene-CH_2-Group together with a Study in Coumarin Condensations.*	Dr. K. G. NAIK	Dr. SHRI KRISHNA (Lahore)	Distinction
DESAI, H. R.	*Investigations on the Interaction of Sulphuryl Chloride with Substances containing the Reactive Methylene CH_2- Group together with a Study of the Graduated Reduction of the Chloro Compounds obtained and also a Study in Coumarin Condensation.*	Dr. K. G. NAIK	Dr. SHRI KRISHNA (Lahore)	Pass
GAJENDRAGAD, N. G.	*Equilibrium Constants of some simple Reactions in Organic Chemistry.*	Dr. H. E. WATSON	Dr. N. R. DHAR (Allahabad)	Pass
MEHTA, S. M.	*Sodium Borate Solution and Acid Effect of Temperature.*	Dr. A. N. MELDRUM	Dr. S. S. BHATNAGAR (Lahore)	Pass
SASTRY, B. N.	*Methods of Preparation and Investigation of Enzymes.*	Prof. V. SUBRAHMANYAN	Dr. GILBERT J. FOWLER	Pass

SHINTRE, V. P.	*Composition of the Essential Oil from the wood Erythroxylon Mongynum Roxb.*	Dr. H. E. WATSON	Mr. M. GOPAL RAO (Dehra Dun)	Distinction
1929				
BASETTIHALLI K. HANUMANTHA RAO	*Studies in some Chemical Aspects of the Nutrition of the lac insect.*	Prof. R. V. NORRIS	Dr. H. H. MANN (Woburn, Research Stn., England)	Distinction
BOKIL, K. V.	*Study of Aromatic Sulphones and allied Sulphur Derivatives of o-Cresol methyl-ether.*	Prof. G. B. KOLHATKAR	Dr. K. G. NAIK	Distinction
DESHPANDE, R. K.	*Part I. A Simplified Method for the Preparation of Anilides.* *Part II. Condensation of Anilides with Aromatic Tertiary Amines—A synthesis of p-dialkylamino-benzophenones.*	Prof. R. C. SHAH & Dr. A. N. MELDRUM	Prof. R. ROBINSON (Univ. College, London)	Distinction
GODBOLE, R. D.	*Studies in Reactions in Mixed Solvents*	Dr. MATA PRASAD	Prof. J. C. PHILIP (Roy. College. of Sc., London)	Distinction
HATTIANGADI, R. R.	*Studies in Silicic Acid Gels.*	Dr. MATA PRASAD	Dr. S. S. BHATNAGAR (Lahore)	Distinction
NUGGIHALLI NARAYANA	*Studies in Vegetable Proteins.*	Prof. R. V. NORRIS	Prof. R. H. PLIMMER (Uni. Coll. of London)	Distinction
PAREKH, M.M.	*A Study of the Interaction of Thioyl Chloride with Substances containing a Reactive Methylene* $(CH)_2$ *Group. A contribution to the Chemistry of Organic Sulphur Derivatives derived from Thionyl Chlorides.*	Dr. K. G. NAIK	Dr. SHRI KRISHNA	Distinction

Name of the Candidate	Subject of the Thesis	Name of the Professor under whom the candidate worked	Name of the Referee	Remarks
PATEL, A. M.	*Studies in Thorium Hydroxide Sol.*	Dr. A. R. NORMAND	Dr. S. S. BHATNAGAR (Lahore)	Distinction
REWADIKAR, R. S.	*Preparation and Properties of a Monoglyceride.*	Dr. H. E. WATSON	Dr. H. K. SEN (Calcutta University)	Distinction
SHAH, C. C.	*A Study of the Hydrogen Atoms of a Methylene ($-CH_2-$) Group situated between the Carbonyl (CO) Groups, with the help of Iodine Monochloride and Mercuric Chloride.*	Dr. K. G. NAIK	Dr. SHRI KRISHNA (Forest Research Institute, Dehra Dun)	Distinction (R. R. Desai Gold Medal)
VAD, G. M.	*Part I. The Chloral and Bromal Derivatives of the Polyhydric Alcohols.* *Part II. The Action of Halogens on Dichloro Ethyl Acetamide.*	Dr. A. N. MELDRUM	Prof. W. N. HAWORTH (Birmingham Univ.)	Distinction
VAIDYANATHAN, K. S.	*Synthesis of Substances related to Cochinillic and Carminic Acids.*	Dr. A. N. MELDRUM	Prof. R. ROBINSON (London University)	Distinction
VARDHAN, C.	*Studies in Petrol Water Emulsions.*	Dr. H. E. WATSON	Prof. G. B. KOLHATKAR	Distinction
DALVI, P. D.	*The Biochemistry of the Fermentation of Tan Liquors.*	Prof. R. V. NORRIS	Dr. GILBERT J. FOWLER	Pass
DESHPANDE, D. D.	*Power Alcohol and Paper from Rice Straw.*	Prof. R. V. NORRIS	Dr. GILBERT J. FOWLER (Tech. Institute, Cawnpore)	Pass
DURAI SWAMI, N.	*Enzyme Action. I. The Nature of Diastase. II. Tyrosinase.*	Prof. R. V. NORRIS	Prof. D. L. SAHASRABUDHE	Pass

NARWANI, C. S.	*Studies in Chromatic Emulsions :—* *Part I. Experimental Technique employed in the Preparation of Stable Multicoloured Emulsions.* *Part II. Theory of Stability of Chromatic Emulsions from the standpoint of their Viscosities and Interfacial Tension.*	Dr. S. S. BHATNAGAR	Dr. J. N. MUKERJEE (Calcutta University)	Pass
NIGUDKAR, K. D.	*Studies in the Photo-Reduction of Ferric Chloride in non-aqueous solutions.*	Dr. MATA PRASAD	Dr. J. C. GUHA (Dacca University)	Pass
TATA, A. S.	*The Reactions of Chloral Derivatives.*	Dr. A. N. MELDRUM	Prof. D. D. KANGA	Pass
1930				
BETRABET, M. V.	*Colour in relation to Chemical Constitution.*	Dr. G. C. CHAKRAVARTI	Dr. F. A. MASSON (Chem. Dept., Manchester).	Distinction
DIXIT, V. M.	*The Condensation of Phenols and Phenolic Ethers with Acetone-dicarboxylic Acid.*	Mr. D. B. LIMAYE & Dr. A. N. MELDRUM	Prof. R. ROBINSON (University College, London)	Distinction (R. R. Desai Gold Medal)
IYER, B. H.	*1. Acridine and Benzoquinoline derivatives. 2. Cantharidin from " Mylabus Pustulata " Fb. 3. Fat from " Mylabus Pustulata " Fb.*	Dr. P. C. GUHA & Dr. G. C. CHAKRAVARTI	Prof. R. ROBINSON (University College, London)	Distinction
KANE, J. G.	*Adsorption from Solutions.*	Prof. S. K. KULKARNI-JATKAR	Dr. J. N. MUKERJEE	Distinction
KATRAK, BHIKAIJI N. (Miss)	*Condensation of Butyl Chloral Hydrate with Gallic Acid and the Cresotic Acid.*	Dr. A. N. MELDRUM	Dr. P. C. MITTER (Calcutta)	Distinction

Name of the Candidate	Subject of the Thesis	Name of the Professor under whom the candidate worked	Name of the Referee	Remarks
MUDAMBAI, VENUGOPALAN	*Contributions to the Scientific Study of Lac Industry.*	Mrs. DOROTHY NORRIS	Dr. G. J. FOWLER	Distinction
NADIGAR NARASINHA MURTY	*Some Biochemical Aspects of the Spike Disease of Sandal.*	Dr. R. V. NORRIS & Mr. V. SUBRAHMANYAN	Dr. G. J. FOWLER	Distinction
PANDYA, D. B.	*The Group—NH. CHOH. CCl_3 and the Group NH. CH_2—$CHCl_2$.*	Dr. A. N. MELDRUM	Dr. M. O. FORSTER	Distinction
PATEL, S. M.	(1) *Chemistry of Fixed Oils and* (2) *Optical Activity of some Derivatives of Camphorquinone.*	Dr. P. C. GUHA	Prof. T. P. HILDITCH (Liverpool)	Distinction
PATEL, Z. H.	(1) *Studies in the Alcoholysis of the Esters of Dibasic Acids.* (2) *Alcoholysis in Mixed Solvents.* (3) *Solidification Points of Capric and Stearic Acids and their Mixtures.*	Prof. S. K. KULKARNI-JATKAR	Prof. G. B. KOLHATKAR	Distinction
PATWARDHAN, V. A.	*Synthesis of Fatty Acids and the Composition of Fixed Oils from the seeds of* (2) *Ocimum Basilicum* (*Lum*) *and* (3) *Amoora Rohituka* (*W. and A.*)	Dr. P. C. GUHA	Prof. T. P. HILDITCH	Distinction
RAO, G. G.	*The Density and Compressibility of Silanes, Dielectric Constants of Gases, the Heat of Neutralisation and Dissociation Constant of Eugenol and Isoeugenol.*	Prof. S. K. KULKARNI-JATKAR	Prof. F. L. USHER (Leeds University)	Distinction

	thesis in leaves in Artificial Light and in Neutral Light.		(Liverpool)	
SHAH, L. D.	*A Study in the Formation of the Properties of the Organometallic Derivatives of Compounds containing a Reactive Methylene.*	Dr. K. G. NAIK	Dr. C. K. INGOLD (Leeds University)	Distinction
TENDULKAR, M. G.	*Studies in Nickelous Oxide.*	Dr. MATA PRASAD	Prof. J. R. PARTINGTON (East. Lon. Coll., London)	Distinction
BELI, S. V. K. V.	*The Conductivity and Viscosity Measurements of Solutions of pure Soaps in Absolute Ethyl Alcohol, Alcohol-water Mixtures and Waters.*	Prof. S. V. KULKARNI-JATKAR	Dr. S. S. BHATNAGAR (Lahore)	Pass
CHAUBAL, J. S.	*(1) Condensation of Anilideimidechlorides with Tertiary Amines.* *(2) Reaction between Benzanilideimilochloride and Tertiary Amines.* *(3) Synthesis of N-alkyl-di-aryl-benzenylamidines.*	Prof. R. C. SHAH	Dr. J. L. SIMONSEN	Pass
CHOKSEY, N. B.	*Studies in Magneto Electro Chemical Phenomena and a Galvanometer Method for Electrical Conductivity Measurements of Solutions.*	Dr. MATA PRASAD	Dr. A. J. ALLMAND (King's College, London)	Pass
DESAI, P. N.	*Researches in the Interactions of Oxalyl Chloride with Substances containing a Reactive Methylene (-CH$_2$-) Group. A Contribution to the Chemistry of Closed Carbon Chains*	Dr. K. G. NAIK	Dr. C. K. INGOLD (University of Leeds)	Pass

Name of the Candidate	Subject of the Thesis	Name of the Professor under whom the candidate worked	Name of the Referee	Remarks
GHASWALLA, R. P.	*Decomposition of Phenol and Naphthol Ethers through Hydrochloric Acid.*	Prof. G. B. KOLHATKAR	Dr. H. E. WATSON	Pass
JOSHI, N. G.	*Aqueous Solutions of Sodium Aluminate.*	Prof. S. M. MEHTA	Prof. J. R. PARTINGTON (East London College)	Pass
KOTWAL, R. D.	*Condensation of Chloral with Succinic Acid.*	Dr. A. N. MELDRUM	Dr. P. C. MITTER (Calcutta)	Pass
PARIKH, P. H.	*Synthesis of Phenylacetic Acids and m-hemipinic acid.*	Dr. A. N. MELDRUM	Dr. B. B. DEY (Madras)	Pass
PATEL, P. P.	*Synthesis of Organic Polysulphides, Thiodiazoles etc. and Synthesis of bicyclic terpene Derivatives.*	Drs. P. C. GUHA & G. C. CHAKRAVARTI	Dr. K. G. NAIK	Pass
SHAH, N. M.	*(1) The Condensation of m-cresotic acid with Chloral.* *(2) Sodium Hydrogen Phosphate Solutions.*	Prof. R. L. ALIMCHANDANI	Prof. D. D. KANGA	Pass
1931				
LAKHANI, M. P.	*Studies in Liesegang Rings and Effect of Electrolytes on Silica, etc.*	Dr. S. S. BHATNAGAR	Dr. J. N. MUKERJI	Pass
KALE, N. P.	*(1) A Biochemical Study of the Formation (ii) the Composition of the Oil in the Niger Seed (Guizotia Abyssinica).*	Rao Bahadur Prof. D. L. SAHASRABUDHE	Dr. T. K. WALKER (Coll. of Tech., Manchester)	Distinction

KHUBCHANDANI, K. W.	*Manufacture of Sulphuric Acid by the Contact Press with Vanadium Catalysts.*	Dr. H. E. WATSON	Dr. J. R. PARTINGTON (University of London)	Distinction
NABAR, G. M.	*Studies in Colloids.*	Dr. A. R. NORMAND	Dr. H. FREUNDLICH (Berlin-Dahlem)	Distinction (R. R. Desai Gold Medal)
OZA, T. M.	*Attempts to make out the Mechanism of Chemical Reactions.*	Dr. M.S. SHAH & Prof. D. D. KANGA	Prof. H. B. BAKER (Roy. Coll. of Sc., London)	Distinction
RAGHUNATHA RAO, Y.K.	*A Study of Wood-Tar and its Utilisation.*	Dr. H. E. WATSON	Prof. G. T. MORGAN (Teddington)	Distinction
SHAIKH, A. M.	*The Condensation with Chloral of Amides and Ketonic Ester and the Condensation with Bromal of Amides and Urethanes.*	Dr. A. N. MELDRUM	Prof. R. ROBINSON (Oxford)	Distinction
CHOKKANNA, N. G.	*Electromotive Behaviour of two cells* (*a*) $Pt./\frac{CuO}{Cu_2O}N.\ Na.\ OH$ (*b*) $Pt./\frac{Fe(OH)_3}{Fe(OH)_2}N.\ Na.\ OH.$	Dr. MATA PRASAD	Prof. JONES P. KENDALL (University of Edinburgh)	Pass
DESIKACHAR, N.	(*1*) *The Decomposition of Organic Matter in the Soil and its Relation to Soil Fertility.* (*2*) *Studies on Enzyme Action.* (*3*) *Industrial Alcohol from Carica Papaya.* (*4*) *Carbohydrate Changes during the ripening of Plantains.*	Dr. V. SUBRAHMANYAN	Sir JOHN RUSSEL (Herts, England)	Pass

Name of the Candidate	Subject of the Thesis	Name of the Professor under whom the candidate worked	Name of the Referee	Remarks
DHAIRYAWAN, A. K.	*Condensations of Bromalhydrate with Urea and Thiourea and their derivatives.*	Dr. A. N. MELDRUM	Prof. J. L. SIMONSEN (Bangor)	Pass
KARMARKAR, D. V.	(1) *Studies on Plant Amylases.* (2) *Chemical Study of the Germination of Ground-nut.* (3) *Storage of Mangoes.* (4) *A Note on the Ripening of Banana.*	Dr. V. SUBRAHMANYAN	Prof. A. R. LING (Birmingham)	Pass
KOTWANI, G. S.	*The Action of Hydrogen Sulphide on a 5-p. c. Solution of Chromic Acid.*	Dr. H. B. DUNNICLIFF	Dr. J. R. PARTINGTON (University of London)	Pass
LONKAR, K. V.	*Condensation of Phenols with Chloral.*	Dr. A. N MELDRUM	Dr. F. D. CHATTAWAY (Oxford)	Pass
MAPARA, H. M.	*X-Ray Investigation of the Crystals of Copper Formate Dihydrate and Cadmium Formate Dihydrate.*	Dr. MATA PRASAD	Dr. J. D. BERNAL (Mineralogical Museum, Oxford)	Pass
MISTRY, S. M.	(1) *Aromatic Organo-Antimony Compounds.* (2) *An Improved Method of Preparation of Substituted Amides and Hydrazides* (3) *Studies in Abnormal Optical Rotation.*	Dr. P. C. GUHA	Prof. G. T. MORGAN (Teddington)	Pass

RAMASWAMY, K. L.	(1) *Dielectric Constants of Gases.* (2) *Densities and Compressibilities of Hydrocarbons.* (3) *Behaviour of Freshly Precipitated Lead Chromate.*	Dr. H. E. WATSON	Dr. JAMES WALKER (University of Edinburgh)	Pass
SATHE, T. R.	(1) *Studies on the Pigments of Lantana Camara.* (2) *Calcium Contents of Blood Serum in Disease.* (3) *Relations between Seeds and their accompanying micro-flora.*	Dr. V. SUBRAHMANYAN	Prof. A. R. LING (Uni. of Birmingham)	Pass
SOHONI, N. V.	*The Photo-Reduction of Ferric Chloride in Alcoholic Solutions.*	Dr. MATA PRASAD	Prof. E. C. C. BALY (University of Liverpool)	Pass
DESAI, J. B.	*Studies in Silicic Acid Gels.*	Dr. MATA PRASAD	Prof. J. N. MUKERJI (Calcutta University)	Distinction
GOGTE, G. R.	*Part I. Condensation of Acetone Dicarboxylic Acid with para and meta Cresolmethyl ethers.* *Part II. Oxidation of Embelin with Nitric Acid.*	Mr. D. B. LIMAYE	Prof. C. K. INGOLD (University College, London)	Distinction
KAREKAR, N. V.	*Studies in Thorium Hydroxide Sol.*	Dr. A. R. NORMAND	Prof. J. M. MUKERJI (Calcutta University)	Distinction
PATEL, R. P.	*A Study in the Preparation and Properties of Organomercury Compounds containing a Reactive Methylene* (CH_2) *Group situated between two negative groups by means of Mercuric Acetate and Mercuric Chloride.*	Dr. K. G. NAIK	Prof. J. F. THORPE (Imp. College of Sc. and Tech. London)	Distinction (Moos Medal)

Name of the Candidate	Subject of the Thesis	Name of the Professor under whom the candidate worked	Name of the Referee	Remarks
THOSAR, V. B.	*A Study of the Reaction of Thionyl Chloride with Substances containing a Reactive Methylene (CH_2) Group under different conditions.*	Dr. K. G. NAIK	Prof. J. F. THORPE (Imp. Coll. of Sc. and Tech. London)	**Distinction**
PAREKH, V. C.	*I. Attempts to synthesise -p-diphenylene and the Study of the Molecular Complexity of the Oxidised Product of P-dimercaptan of Benzene.* *II. Asymetric Synthesis of Tetravalent Sulphur Atom.* *III. The Constitution of the Fatty Acids occurring in Morings Pterigosperma Seed Oil.* *IV. The Chemical Composition of Mysore Chrysalis Oil.* *V. Action of Magnesium on some higher n-alkyl Iodides from C_{12} onwards.*	Dr. P. C. GUHA	Prof. C. K. INGOLD (University College, London)	**Pass**
BARVE, P. M.	*Studies in Positive Hydrosols.*	Dr. A. R. NORMAND	Prof. D. W. OSTWALD	**Distinction**
1932				
BHATT, C. T.	*Studies in Thiol Series—The Thiol Derivatives of (a) O, M and P-Methoxy-Toluenes and (b) O, M and P-Methoxy Benzoic Acids.*	Prof. D. D. KANGA & Dr. M. S. SHAH	Prof. S. SMILES, (King's College, London)	**Distinction (R. R. Desai Gold Medal)**

CHOKSI, K. N.	*A Contribution to the Study of Organic Arsenicals together with a Study of the labile nature of the Bromal Atoms substituted in the Reactive Methylene* (CH_2) *Group and the effect of the Negative Character of the adjoining Carbonyl Groups, using phenylhydrazine as a Reagent.*	Dr. K. G. NAIK	Prof. J. F. THORPE (Royal College of Science, London)	Distinction
KAPADIA, B. M.	*Condensation of Chloral with 2-hydroxy-p-toluic Acid and its Methyl Ether.*	Dr. A. N. MELDRUM & Dr. T. S. WHEELER	Dr. F. D. CHATTAWAY (Queen's College, Oxford)	Pass
KELKAR, N. C.	*(1) Constituents of the Volatile Oil from the Roots of Curcuma Longa (Turmeric Oil).* *(2) Formation of Curcumone.* *(3) Chemical Composition of the Volatile Oil from Acorus Calamus.*	Dr. P. C. GUHA	Dr. J. L. SIMONSEN, (University College of North Wales, Bangor)	Distinction
NADKARNY, V. V.	*Studies in Mercuration.*	The Rev. F. J. SACASA, S.J.	Dr. T. S. WHEELER	Pass
NEVGI, G. V.	*Raman Effect in Organic Chemistry.*	Dr. H. E. WATSON	Sir C. V. RAMAN	Distinction
SUNAVALA, S. D.	*Analytical Chemistry :—* *(1) Estimation of Acetone in Methyl Alcohol.* *(2) Estimation of Chlorinated Drinking Waters.* *(3) Estimation of Potassium by the Cobaltnitrite Method.*	Dr. H. E. WATSON	Dr. H. F. HARWOOD (Imp. College of Sc. and Tech.)	Pass

Bibliography of Research in Chemistry in and by the Bombay Presidency from 1901 to 1932

ABBREVIATIONS OF TITLES

Abbreviations	Name of the periodical	Number of papers published.
Arch. Phar.	*Archiv der Pharmazie.*	1
Agri. Jour. Ind. Pusa.	*Agricultural Journal of India, Pusa.*	5
Ber.	*Berichte der deutschen chemischen Gasellschaft.*	1
Biochem. Jour.	*The Biochemical Journal, London.*	2
Bull. Agri. Res. Inst. Pusa.	*Bulletin Agriculture Research Institute, Pusa.*	1
Bull. Dept. Agri. Bom.	*Bulletin of the Department of Agriculture, Bombay.*	13
Bull. Ind. Dept. Bom.	*Bulletin Industries Department Bombay.*	1
Ind. J. Agri. Sc.	*Indian Journal of Agricultural Science.*	1
Ind. J. Med. Res.	*Indian Journal of Medical Research.*	12
Ind. J. Phys.	*Indian Journal of Physics.*	2
J. A. C. S.	*Journal of the American Chemical Society.*	3
J. Bom. Nat. His. Soc.	*Journal of the Bombay Natural History Society.*	6
J. Cen. Bur. Ani. Hus. & Dairy, Ind.	*Journal of the Central Bureau of Animal Husbandry & Dairy, India.*	1
J. C. S.	*Journal of the Chemical Society, London.*	49
J. I. C. S.	*Journal of the Indian Chemical Society.*	53
J. I. I. Sc.	*Journal of the Indian Institute of Science, Bangalore.*	75
J. Phys. Chem.	*Journal of the Physical Chemistry.*	4
J. Proc. A. S. Ben.	*Journal of the Proceedings of the Asiatic Society of Bengal.*	1
J. S. C. I.	*Journal of the Society of Chemical Industry*	1
J. S. Dyer & Colour.	*Journal of the Society of Dyers & Colourists*	4
Koll. Chem.	*Kolloid Chemische Beihefte.*	2
Kolloid-Z.	*Kolloid-zeitschrift*	2
Mem. Imp. Dep. Agri. Pusa.	*Memoirs of the Imperial Department of Agriculture, Pusa.*	7
Nature	*Nature.*	4
Phil. Mag.	*Philosophical Magazine.*	3
Proc. Roy. Sc.	*Proceedings of the Royal Society.*	1
Rec. trav. Chim.	*Recueil des travaux chimiques des Pays-Bas.*	1
Trans. Am. Elec. Soc.	*Transactions of the American Electrochemical Society.*	1
Trans. Faraday, Soc.	*Transactions of the Faraday Society.*	4

ABBREVIATIONS

Abbreviations	Name of the College or Institute
Balk. Ras. Kap.	The Balkrishna Rasashala Kapilasram, Poona City.
B. C.	Baroda College, Baroda.
Brit. Sec. Malt. & Brew. & Dept. Biochem. Ferm. Birm. Univ.	British Section of Malt and Brewery, Department of Biochemistry and Fermentation, University of Birmingham.
Chem. Lab. Univ. Leip.	Chemical Laboratory, University of Leipzig.
Coll. Tech. Manch.	College of Technology, Manchester.
Corn. Univ.	Cornell University, U. S. A.
D. J. S. C.	D. J. Sind College, Karachi.
Dept. Biochem. Ferm. Univ. Birm.	Department of Biochemistry of Fermentation, University of Birmingham.
Edin. Univ.	Edinburgh University.
F. C.	Fergusson College, Poona.
F. C. L.	Foreman Christian College, Lahore.
G. C. L.	Government College, Lahore.
I. I. S.	Indian Institute of Science, Bangalore.
Imp. Coll. Sc. & Tech. Lond.	The Imperial College of Science and Technology, London
K. C.	Karnatak College, Dharwar.
Liv. Univ.	Liverpool University.
M. R. S. I. G. C.	Madhaolal Ranchodlal Science Institute, Gujarat College, Ahmedabad.
Pharm. Lab.	Pharmacological Laboratory, Bombay.
R. I. E. I.	The Ranade Industrial and Economic Institute, Poona.
Ras. Nid. Kap.	The "Rasayan-Nidhi" Kapilashram, Poona.
Res. Lab. Math. & Niag. Alk. W.	Research Laboratory of Mathieson and Niagara Alkali Works, U. S. A.
R. I. S.	Royal Institute of Science, Bombay.
Roy. Inst. Sc. & Davy Fara. Lab.	Royal Institute of Science and Davy Faraday Laboratory.
S. P. C.	Sir Parshurambhau College, Poona.
Univ. Minn.	University of Minnesota, U. S. A.
W. C.	Wilson College, Bombay.
X. C.	St. Xavier's College, Bombay.

*Bibliography of Research in Chemistry in and by the Bombay Presidency from 1901 to 1932**

Total Number of Original Papers in Inorganic and Physical Chemistry ...	66
" " " " " " Organic Chemistry	124
" " " " " " Biochemistry	71
Grand Total ...	261

Year of publication	Title of the paper	Name or Names of the Author or Authors	Where published	Name of the Institute where the work was done
1910	*Salt Lands of the Nira Valley.*	H. H. MANN & V. A. TAMHANE	*Bull. Dept. Agri. Bom.*, No. 39	...
1911	*The Composition of Milk of some Breeds of Indian Cows and Buffaloes. Part I*	MEGGIT & H. H. MANN	*Mem. Dept. Agri.*, Pusa, Vol. II, No. 1.	...
1912	*The Composition of Milk of some Breeds of Indian Cows and Buffaloes. Part II.*	MEGGIT & H. H. MANN	*Mem. Dept. Agri.*, Pusa, Vol. II, No. 4.	...
1912	*The "Rab" System of rice cultivation in Western India.*	H. H. MANN, N. V. JOSHI & N. V. KANITKAR	*Mem. Dept. Agri.*, Pusa, Vol. II, *No. 3.*	...
1913	*The Spontaneous Crystallisation of solutions of Potassium Chloride, Potassium Bromide and Potassium Iodide.*	B. M. JONES & P. G. SHAH	*J. C. S.*	F. C. L. and Imp. Coll. Sc. Tech.
1913	*Studies in the Chemistry and Physiology of the leaves of the Betel vine (Piper Betel) and of the Commercial bleaching of betel vine leaves.*	H. H. MANN, D. L. SAHASRABUDDHE & V. G. PATWARDHAN	*Mem. Dept. Agri.*, Pusa, Vol. III, No. 2.	...

1913	*Condensation of Acid Chlorides with the Ethyl Ester of (a) Cyano-Acetic Acid, (b) Malonic acid and (c) Acetoacetic acid Part I.*	C. WEIZEMANN, H. STEPHAN & G. S. AGASHE	*J. C. S.*	Univ. Manch.
1914	*Lantana Camara, Oil from the flowers and leaves of.*	D. D. KANGA	*J. I. I. S.*	I. I. S.
1914	*Lavandula burmanni, Oil from the flowers and leaves of.*	D. D. KANGA	*J. I. I. S.*	I. I. S.
1914	*Ein aus den Blüten and blättern der Lantana Camara gewonnenes oel.*	D. D. KANGA	*Arch. Phar.*	I. I. S.
1914	*Acid Secretion of the Gram Plant (Cicer Arietinum).*	D. L. SAHASRABUDDHE	*Bull. Agri. Res. Ins.*, Pusa, No. 45	...
1914	*Notes of the Fat of Garcinia Indica the so-called Kokum butter.*	H. H. MANN & N. V. KANITKAR	*J. & Proc. A. S. Ben.*, Vol. X., No. 8.	...
1914	*The Reaction of Trioxymethylene on various Hydrocarbons in the presence of Aluminium-chloride.*	V. R. KOKATNUR & G. B. FRANKFORTER	*J. A. C. S.*	Uni. of Minn.
1914	*Chemical Examination of the Root of "Nerium Odorum", Part I.*	S. T. GADRE	*J. I. I. S.*	I. I. S.
1915	*Well waters from the Trap area of Western India.*	H. H. MANN	*Bull. Agri. Dept.*, No. 73 (Bom.)	...
1915	*Dilatometric determination of the Velocity of Alcoholysis in the presence of large excess of alcohol. Part I.*	G. B. KOLHATKAR	*J. C. S.*, 921, *107*, 1915.	I. I. S.

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*Every effort has been made to make the bibliography as complete as possible on the basis of information supplied by institutions and authors supplemented by further investigations in Journals.

Year of publication	Title of the paper	Name or Names of the Author or Authors	Where published	Name of the Institute where the work was done
1915	*The Velocity of ionisation at low temperatures.*	A. R. NORMAND	*J. C. S.*	W. C.
1916	*Studies in the Chemistry and Physiology of the leaves of the Betel vine (Piper Betel) and of the Commercial bleaching of the betel vine leaves.*	H. H. MANN & V. G. PATWARDHAN	*Mem. Dept. Agri.*, Pusa, Vol. IV, No. 7	...
1917	*The Spice Gardens of Sirsi in Kanara.*	D. L. SAHASRABUDDHE	*Bull. Dept. Agri.*, Bom. No. 83. (3)	...
1917	*Displacement of Sulphonic acid groups in amino-sulphonic acids by halogen atoms.*	J. J. SUDBOROUGH & J. V. LAKHANI	*J. I. I. S. and J. C. S.*	I. I. S.
1917	*The Determination of the Iodine Value of Fats and Oils by Winkler's Bromate method.*	J. V. LAKHANI & J. J. SUDBOROUGH	*J. I. I. S.*, Vol. I, Part 17.	I. I. S.
1917	*Manufacture of Thymol from Ajowan.*	J. V. LAKHANI, J. J. SUDBOROUGH & H. E. WATSON	*J. I. I. S.*, Vol. 4, Part 5. (4	I. I. S.
1918	*The artificial Manures—experiments on their value for crops in Western India, Nos. I and II.*	H. H. MANN & S. R. PARANJPE	*Bull. Dept. Agri.*, Bom. No. 89	...
1918	*Alcoholysis in the absence of a catalyst.*	BHAGWAT, BHAGVAT & SUDBOROUGH	*J. I. I. S.*	I. I. S.

1918	*Decomposition of phenol and naphthol ethers in the presence of concentrated hydrochloric acid.*	G. B. KOLHATKAR	*J. I. I. S.*	I. I. S.
1918	*Commercial Uses of Chlorine.*	V. R. KOKATNUR	*Trans. Am. Elec. Chem. Soc.*	Res. Lab. Math. & Niag. Alk. W.
1918	*Studies on the sulphonation of* β-*naphthylamine.*	A. G. GREEN & KAPILRAM H. VAKIL	*J. C. S.*	Coll. Tech. Manch.
1919	*Safflower Oil as a drying oil.*	H. H. MANN & N. V. KANITKAR	*J. S. C. I.*, Vol. XXXVIII	...
1919	*Keto-Enolic change in Carbonyl compounds.*	BHAGWAT & SUDBOROUGH	*J. I. I. S.*	I. I. S.
1919	*The Influence of Catalysis on the Chlorination of Hydrocarbons.*	V. R. KOKATNUR	*J. A. C. S.*	Res. Lab. Math. & Niag. Alk. W.
1919	*Some Enzymes of the Leaf of Lantana Camara.*	J. D. EDAL-BEHRAM & G. J. FOWLER	*J. I. I. S.*	I. I. S.
1919	*Wood Distillation, Parts I and II.*	K. R. DOTIVALA, H. E. WATSON & J. J. SUDBOROUGH	*J. I. I. S.*	I. I. S.
1920	*Studies in Alcoholysis III—the Alcoholysis of aromatic esters and the inhibiting influence of ortho-substituents.*	J. J. SUDBOROUGH & D. D. KARVE	*J. I. I. S.*	I. I. S.
1920	*Additive Compounds of arylamines with nitro derivatives of naphthalene.*	J. J. SUDBOROUGH, NORMAN PICTON & D. D. KARVE	*J. I. I. S.*	I. I. S.

Year of publication	Title of the paper	Name or Names of the Author or Authors	Where published	Name of the Institute where the work was done
1920	*Investigation into the Nature of Salt Lands in Sind.*	V. A. TAMHANE	*Bull. Dept. Agri.*, Bom., No. 96	...
1920	*Fodder Crops of Western India.*	H. H. MANN	*Bull. Dept. Agri.*, Bom., No. 100	...
1920	*Investigations on Potato Cultivation in Western India.*	H. H. MANN, B. M. JOSHI & others	*Bull. Dept. Agri.*, Bom., No. 102	...
1920	*Gur Making from the juice of the Date Palm in the Thana District of the Bombay Presidency.*	V. G. PATWARDHAN	*Agri. Jour. Ind.*, Pusa, Vol. XV, No. 5	...
1920	*A Preliminary Note of the effect of waterings on the amount of acids secreted by the gram plant* (*Cicer Arietinum*).	D. L. SAHASRABUDDHE	*Agri. Jour. Ind.*, Pusa, Vol. XV, No. 6	...
1920	*Derivatives of Gallic Acid, Part I. Synthesis of 4-Hydroxy-3:5-Dimethoxy-phthalic acid.*	R. L. ALIMCHANDANI & A. N. MELDRUM	*J. C. S.*	M. R. S. I. G. C.
1920	*The Perishing of paper in Indian Libraries.*	J. J. SUDBOROUGH & Miss MANECK M. MEHTA	*J. I. I. S.*, Vol. III, Part 7	I. I. S.
1920	*Wood Distillation, Part III.*	K. R. DOTIVALA, H. E. WATSON & J. J. SUDBOROUGH	*J. I. I. S.*	I. I. S.
1921	*Casein.*	A. N. MELDRUM & GANGULI	*Bull. Ind. Dept*, Bom.	M. R. S. I. G. C.

1921	*Derivatives of Gallic Acid Part II. Gallic Acid (and the Cresotic Acids) and Chloral.*	R. L. ALIMCHANDANI & A. N. MELDRUM	*J. C. S.*, Vol. *119*, p. 201	M. R. S. I. G. C.
1921	*Additive compounds of m-dinitrobenzene.*	D. D. KARVE & J. J. SUDBOROUGH	*J. I. I. S.*	I. I. S.
1921	*Action of methyl and ethyl alcohols on esters of 2:6 dinitro and 2:4:6-trinitro benzoic acids.*	J. J. SUDBOROUGH & D. D. KARVE	*J. I. I. S.*	I. I. S.
1921	*Interaction of sulphur monochloride and Organic Acid amides.*	K. G. NAIK	*J. C. S.*	Imp. Coll. Sc. & T Lond.
1921	*Formation and properties of Dithioketones and Dithioethers. Part I.*	K. G. NAIK	*J. C. S.*	Imp. Coll. Sc. & T Lond.
1921	*Formation and Properties of Dithioketones and Dithioethers. Part II.*	K. G. NAIK	*J. C. S.*	Imp. Coll. Sc. & Te
1922	*Influence of s. trinitrobenzene on reactions in which Arylamines are involved.*	R. C. SHAH & J. J. SUDBOROUGH	*J. I. I. S.*	I. I. S.
1922	*Studies in Acidolysis:* *I. The equilibrium between acetic acid, trichloracetic acid and their ethyl esters.* *II. The equilibrium between acetic acid, trichloracetic acid and their methyl esters.*	J. J. SUDBOROUGH & D. D. KARVE	*J. I. I. S.*	I. I. S.
1922	*Formation and Properties of Dithioketones and Dithioethers, Part III.*	K. G. NAIK & M. D. AVASARE	*J. C. S.*	B. C.

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1922	*The Extraction of Caffeine.*	H.E. WATSON, K. M. SHETH & J. J. SUDBOROUGH	*J. I. I. S.*	I. I. S.
1923	*The constitution of Sulpho-salicylic acid and of related substances.*	A. N. MELDRUM & M. S. SHAH	*J. C. S.*	M. R. S. I. G. C.
1923	*The action of bromine on p-hydroxy and p-methoxy sulphonic acids.*	A. N. MELDRUM & M. S. SHAH	*J. C. S.*	M. R. S. I. G. C.
1923	*Chemical Studies of the safflower seed and its germination.*	V. A. TAMHANE	*Mem. Dept. Agri.*, Pusa, Vol. VI, No. 7	...
1923	*Keto-Enolic change in Carbonyl compounds.*	V. K. BHAGWAT	*J. C. S. & J. I. I. S.*	I. I. S.
1923	*The Correlation between the chemical Composition of Anthelmintics and their therapeutic Values in connection with the Hookworm Inquiry in the Madras Presidency.—XVII. Antiseptics.*	J. F. CAIUS & K. S. MHASKAR	*Ind. Jour. Med. Research*, XI, 1.	X. C.
1923	*XVIII. Cathartics.*	J. F. CAIUS & K S. MHASKAR	*Ind. Jour. Med. Research*, XI, 1.	X. C.
1923	*XIX. Drugs allied to Thymol.*	J. F. CAIUS & K. S. MHASKAR	*Ind. Jour. Med. Research*, XI, 2.	X. C.
1923	*XX. Carbon Tetrachloride.*	J. F. CAIUS & K. S. MHASKAR	*Ind. Jour. Med. Research*, XI, 2.	X. C.

1923	*XXI. Miscellaneous Anthelmintics.*	J. F. CAIUS & K. S. MHASKAR	*Ind. Jour. Med. Research*, XI, 2.	X. C.
1923	*XXII. Summary and Conclusions.*	J. F. CAIUS & K. S. MHASKAR	*Ind. Jour. Med. Research*, XI, 2.	X. C.
1923	*Notes on Ascaricides.*	J. F. CAIUS & K. S. MHASKAR	*Ind. Jour. Med. Research*, XI, 2.	X. C.
1923	*Notes on the Concentration of Anticobra Serum.* *I. Concentration in vacuo and Dilution.*	J. F. CAIUS & K. R. K. IYENGAR	*Ind. Jour. Med. Research*, XI, 2.	X. C.
1923	*The Preparation of Xylose from Maize Cobs.*	A. R. LING &. D. R. NANJI	*J. C. S.*	Dept. Biochem. of Ferm., Birm. Uni.
1923	*Studies on Starch, Part I. The Nature of Polymerised Amylose and of Amylopectin.*	A. R. LING & D. R. NANJI	*J. C. S.*	Dept. Biochem. of Ferm., Birm. Uni.
1923	*Ring-Chain Tautomerism, Part VII. The αββ Trisubstituted. Glutaric acid Type.*	K. C. PANDYA & J. F. THORPE	*J. C. S.*	Imp. Coll. Sc. Tech. Lond.
1923	*Studies in Esterification.*	G. D. ADVANI & J. J. SUDBOROUGH	*J. I. I. S.*	I. I. S.
1923	*Hongay Oil.*	R. D. DESAI, J. J. SUDBOROUGH & H. E. WATSON	*J. I. I. S.*	I. I. S.
1923	*Cashew Kernel Oil.*	C. K. PATEL, J. J. SUDBOROUGH & H. E. WATSON	*J. I. I. S.*	I. I. S. X 3

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1923	*A Chemical Examination of samples of water and of shells from the Inley Valley.*	G. J. FOWLER & M. A. MALANDKAR	*J. I. I. S.*	I. I. S.
1923	*The conversion of Eugenol into Iso-eugenol.*	S. K. GOKHALE, J. J. SUDBOROUGH & H. E. WATSON	*J. I. I. S.*	I. I. S.
1924	*Studies relating to the Symbiosis of Seeds and Bacteria.*	G. J. FOWLER & Miss R. K. CHRISTIE	*J. I. I. S.*	I. I. S.
1924	*The Bio-Genesis of Mahua Oil.*	G. J. FOWLER & T. DINANATH	*J. I. I. S.*	I. I. S.
1924	*Aluminium Amalgam as a Reducing Agent in the Sugar Series.*	D. R. NANJI & F. J. PATON	*J. C. S.*	Dept. Biochem. of Ferm., Birm. Uni.
1924	*Iodine as a Catalyst in Reactions involving Elimination of Hydrogen Halides.*	R. D. DESAI	*J. I. I. S.*	I. I. S.
1924	*Absorption of halogens by Mercurous salts.*	K. G. NAIK & M. D. AVASARE	*J. C. S.*	B. C.
1924	*Interaction of Sulphurmonochloride with organic Acid amides. Part II.*	K. G. NAIK & C. S. PATEL	*J. C. S.*	B. C.
1924	*Anticobra Serum: II. Refractivity.*	J. F. CAIUS & A. STEICHEN	*Ind. Jour. Med. Research*, XI, 4.	X. C.

1924	*Anticobra Serum: III. Separation of the Proteins.*	J. F. CAIUS, K. R. K. IYENGAR & L. A. P. ANDERSON	*Ind. Jour. Med. Research.* XII, 1.	X. C.
1924	*Properties of Neighbouring Hydroxy Groups attached to a Benzene nucleus.*	R. L. ALIMCHANDANI	*J. C. S.*	R. I. S.
1924	*Oil from Minusops Hexandra: Rayan Oil.*	C. K. PATEL	*J. I. I. S.*	I. I. S.
1924	*The Use of Mixed Catalysts in the Hydrogenation of Oils.*	C. K. PATEL	*J. I. I. S.*	I. I. S.
1925	*A Note on an improved device for working a thermostat at low temperatures.*	C. J. J. FOX & C. L. MANKODI	*J. I. C. S.*, 2, 292, 1925.	R. I. S.
1925	*The Reduction of the Group-CH(OH)-CCl_3. Part I.*	A. N. MELDRUM & R. L. ALIMCHANDANI	*J. I. C. S.*, Vol. II. p. 1.	R. I. S.
1925	*Nitrogen Recuperation in the Soils of the Bombay Presidency.*	D. L. SAHASRABUDDHE & J. A. DAJI	*Mem. Dept. Agri.* Pusa, Vol. VIII, No 5	...
1925	*Chemical Composition of grains, fruits and vegetables.*	D. L. SAHASRABUDDHE	*Bull. Dept. Agri.*, Bom., No. 124	...
1925	*Nitro derivatives of 1 : 2 dimethyl glyoxaline.*	BHAGWAT & PYMAN	*J. C. S.*	Coll. Tech. Manch.
1925	*Studies in esterification.*	BHIDE & SUDBOROUGH	*J. I. I. S.*	I. I. S.
1925	*Condensation of carbon-tetrachloride and chloroform with primary aromatic amines.*	R. C. SHAH	*J. I. I. S.*	I. I. S.

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1925	*Studies on Starch, Part II. The Constitution of Polymerised Amyloses, Amylopectin, and their Derivatives.*	A. R. LING & D. R. NANJI	*J. C. S.*	Brit. Sec. Malt. & Brew. and Dept. of Biochem. Ferm., Birm. Uni.
1925	*Studies on Starch, Part III. The Nature and the Genesis of the Stable Dextrin and of the Maltodextrins.*	A. R. LING & D. R. NANJI	*J. C. S.*	Brit. Sec. Malt. & Brew. and Dept. of Biochem. Ferm., Birm. Univ.
1925	*Studies on Starch, Part IV. The Nature of the Amylo-hemicellulose Constituent of certain starches.*	A. R. LING & D. R. NANJI	*J. C. S.*	Brit. Sec. Malt. & Brew. and Dept. of Biochem. Ferm., Birm. Uni.
1925	*An Examination of some Gum Enzymes.*	G. J. FOWLER & M. A. MALANDKAR	*J. I. I. S.*	I. I. S.
1925	*Chemical Constitution of the Gum from Boswellia Serrata.*	M. A. MALANDKAR	*J. I. I. S.*	I. I. S.
1925	*Industrial Wastes as Manure.* *I. Ajowan and Mohua cakes as Fertilisers.* *II. Utilisation of Refuse.*	R. D. REGE	*J. I. I. S.*	I. I. S.
1925	*Constitution of Manasse's Hydroxy-camphor.*	M. O. FORSTER & P. P. SHUKLA	*J. I. I. S.*	I. I. S.

1925	*Biochemical and Histological Studies on Lignification.* *Part I. The Nature of Lignin: Its physiological significance and its estimation in Timbers.*	Miss MANECK M. MEHTA	*Biochem. Jour. Lond.*	Dept. Biochem. Ferm., Birm. Uni.
1925	*Biochemical and Histological Studies on Lignification.* *Port II. Histological studies on the polysaccharides and Aromatic constituents of the cell wall.*	Miss MANECK M. MEHTA	*Biochem. Jour. Lond.*	Dept. Biochem. Ferm., Birm. Uni.
1925	*Anticobra Serum: IV. Absorption Spectrum.*	J. F. CAIUS & A. STEICHEN	*Ind. Jour. Med. Research*, XII, 3.	X. C.
1925	*The effect of Storage on the Potency of Antivenomous Serum.*	L. A. P. ANDERSON & J. F. CAIUS	*Ind. Jour. Med. Research*, XIII, 1.	X. C.
1925	*Thermo-chemical Investigations on the constitution of acids in solution.*	D. D. KARVE	*J. I. C. S.*, I, 247.	Chem. Lab. Uni. Leip.
1925	*Investigations on the acid nature of some derivatives of Sulphur, Selenium and Tellurium.*	D. D. KARVE	*J. I. C. S.*, 2, 128.	Chem. Lab. Uni. Leip.
1925	*O-cresoltetrachlorophthalein and some of its derivatives. Iso-ortho-cresol tetrachlorophthalein.*	M. S. PATEL	*J. A. C. S.*	Corn. Uni.
1926	*Conessine.*	D. D. KANGA, P. R. AYYAR & J. L. SIMONSEN	*J. C. S.*	M. R. S. I. G. C. & I. I. S.
1926	*Condensation of Sulphur dichloride with substances containing reactive methylene group.*	K. G. NAIK & G. V. JADHAV	*J. I. C. S.*	B. C.

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1926	*Interaction of Sulphur dichloride with substances containing the Reactive Methylene* ($-CH_2-$) *Group.*	K. G. NAIK & G. V. JADHAV	*J. I. C. S.*	B. C.
1926	*The Fat from 'Salvadora Oleoides': Khakan Fat.*	C. K. PATEL, N. IYER, J. J. SUDBOROUGH & H. E. WATSON	*J. I. I. S.*	I. I. S.
1926	*An X-Ray Investigation of the Normal Saturated Dicarboxylic acids and their Ethyl Esters.*	A. R. NORMAND, J. D. M. ROSS & E. HENDERSON	*J. C. S.*	Edin. Uni.
1926	*The Production of Ether by solid catalysts.*	S. K. KULKARNI-JATKAR & H. E. WATSON	*J. I. I. S.*	I. I. S.
1926	*Reactions of Chromates at High Temperatures. Part II. The System* $CaO-Cr_2O_3-O_2$.	K. S. NARGUND & H. E. WATSON	*J. I. I. S.*	I. I. S.
1927	*A Study of Indian Medicinal Plants. I. Holarrhena antidysenterica. Wall.*	J. F. CAIUS & K. S. MAHASKAR	*Ind. Med. Research Memoirs*, Memoir No. 6.	Pharm. Lab.
1927	*The bactericidal action of the commoner phenols and of some of their derivatives on Bacillus pestis.*	J. F. CAIUS, B. P. B. NAIDU & SHAMSHER JANG	*Ind. Jour. Med. Research*, XV, 1.	Pharm. Lab.
1927	*The bactericidal action of some organic compounds of Mercury on Bacillus pestis.*	J. F. CAIUS, S. A. KAMAT & B. P. B. NAIDU	*Ind. Jour. Med. Research*, XV, 2.	Pharm. Lab.

1927	*Chemo-therapy of Bubonic Plague.*	J. F. CAIUS & B. P. B. NAIDU	*7th Congress, F. E. A. T. M.*, Calcutta.	Pharm. Lab.
1927	*The Sodium and Potassium Compounds of Phenol.*	A. N. MELDRUM & M. M. PATEL	*J. I. C. S.*	R. I. S.
1927	*Esterification in Mixed Solvents.*	BHIDE & WATSON	*J. C. S.*	I. I. S.
1927	*Remedy against Die-back disease of citrus plants.*	D. L. SAHASRABUDDHE	*Agri. Jour. Ind.*, Pusa, Vol. XXII, No. 2.	...
1927	*Remedy against Die-back disease of citrus plants.*	D. L. SAHASRABUDDHE	*Agri. Jour. Ind.*, Pusa, Vol. XXII, Part VI.	...
1927	*Detection of stale and dirty milk.*	V. N. GOKHALE	*Agri. Jour. Ind.*, Pusa, Vol. XXII, Part IV.	...
1927	*Synthesis of Coumaryl 4-acetic Acid.*	D. B. LIMAYE	*J. C. S.*	Balk. Ras. Kap.
1927	*Interaction of sulphuryl chloride with substances containing the reactive methylene* ($-CH_2-$) *group.*	K. G. NAIK & M. L. SHAH	*J. I. C. S.*	B. C.
1927	*Formation and Properties of Dithio-ketones and Dithio-ethers. Part IV.*	K. G. NAIK & Y. N. BHAT	*J. I. C. S.*	B. C.
1927	*Condensation of cyan-acetic ester with some aryl and alkyl amines, Preparation of some aryl and alkyl substituted cyanacetamides.*	K. G. NAIK & Y. N. BHAT	*J. I. C. S.*	B. C.
1927	*Iso-Erucic Acid.*	T. J. MIRCHANDANI & J. L. SIMONSEN	*J. I. C. S.*	I. I. S.
1927	*Esterification in Mixed Solvents.*	B. V. BHIDE & H. E. WATSON	*J. I. C. S.*	I. I. S.

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1927	*The Decomposition of Alkaline Earth Sulphates.*	L. A. BHATT & H. E. WATSON	*J. I. C. S.*	I. I. S.
1928	*The Action of Light on Dyed Colours.*	F. SCHOLEFIELD, E. HIBBERT & C. K. PATEL	*J. S. Dyer & Col.*	Coll. Tech. Manch.
1928	*The Action of Light on Cotton dyed with Vat dyestuffs.*	F. SCHOLEFIELD & C. K. PATEL	*J. S. Dyer & Col.*	Coll. Tech. Manch.
1928	*The Influence of Heat on the Affinity of cotton for dyestuffs.*	C. K. PATEL	*J. S. Dyer & Col.*	Coll. Tech. Manch.
1928	*The Action of Light during the bleaching of some coloured Cellulose Materials by Hypochlorites.*	F. SCHOLEFIELD & C. K. PATEL	*J. S. Dyer & Col.*	Coll. Tech. Manch.
1928	*Studies in Enzyme Action. Part I. Amylase from cholam (Sorghum Vulgare).*	V. N. PATWARDHAN & R. V. NORRIS	*J. I. I. S.*	I. I. S.
1928	*A Biochemical Study of Some Soil Fungi with special reference to Ammonia Production.*	A. K. THAKUR & R. V. NORRIS	*J. I. I. S.*	I. I. S.
1928	*Oil from the Seeds of Adenanthera Pavonina. A source of Lignoceric Acid.*	S. M. MUDBIDRI, P. R. AYYAR & H. E. WATSON	*J. I. I. S.*	I. I. S.
1928	*α-iso Propylglutaconic Acid.*	L. V. HARIHARAN, K. N. MENON & J. L. SIMONSEN	*J. I. I. S.*	I. I. S.

1928	*Interaction of chloro-sulphonic acid with Substituted amides of cyanacetic acid.*	K. G. NAIK & M. B. AMIN	*J. I. C. S.*	B. C.
1928	*The 3-and 5-Nitro Salicylic Acids.*	A. N. MELDRUM & N. W. HIRWE	*J. I. C. S.*	R. I. S.
1928	*Nitro derivatives of dibenzyl aniline.*	R. D. DESAI	*J. I. C. S.*	R. I. S.
1928	*Assimilation of Nutrients by rice plants.*	D. L. SAHASRABUDDHE	*Bull. Dept. Agri.*, Bom. No. 154	...
1928	*Note onthe Influence of Hydrolysed Gelatine on the precipitation of Silver Chromate.*	T. R. BOLAM & B. N. DESAI	*Trans. Faraday Soc.*, Vol. *24*, 50, 1928.	Edin. Uni.
1928	*The kinetics of coagulation.*	B. N. DESAI	*Trans. Faraday Soc.*, Vol. *24*, 181, 1928.	Edin. Uni.
1928	*The coagulation of thorium hydroxide sol by electrolytes.*	B. N. DESAI	*Koll. Chem.*, Vol. *26*, 358, 1928.	Edin. Uni.
1929	*Studies in ceric hydroxide sol and gel.*	B. N. DESAI	*Koll. Chem.*, Vol. *26*, 422, 1928.	Edin. Uni.
1929	*Substances related to Cochinillic and Carminic Acids.* *Part II. A. Synthesis of α-Coccinic Acid.*	A. N. MELDRUM & R. L. ALIMCHANDANI	*J. I. C. S.*, Vol. VI, p. 253.	K. C.
1929	*The combustion of charcoal in oxygen, nitric oxide and nitrous oxide.* *Part I. The Adsorption of Oxygen.*	M. S. SHAH	*J. C. S.*	M. R. S. I. G. C.
1929	*The combustion of charcaol in oxygen, nitric oxide and nitrous oxide.* *Part II. The Effect of Temperature.*	M. S. SHAH	*J. C. S.*	M. R. S. I. G. C.

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1929	*The Toxicity of the Venom of Indian Scorpions :* *I. Butheolus melanurus. Kessler.*	J. F. CAIUS	*Jour. Bomb. Nat. Hist. Soc.*, XXXIII, 3.	X. C.
1929	*Earth-eating and Salt-licking in India. Analyses. I–III.*	J. F. CAIUS & K. H. BHARUCHA	*Jour. Bomb. Nat. Hist. Soc.*, XXXIII, 3.	Pharm. Lab.
1929	*Halogenomercuriphenols.*	J. F. CAIUS & J. H. WADIA	*Journ. Bom. Nat Hist. Soc.*, VI, 4.	Pharm. Lab.
1929	*A Study of the Soils associated with the Deterioration of the Cardamon crop in North Kanara.*	D. L. SAHASRABUDDHE & G. M. BAPAT	*Bull. Dept. Agri.*, Bom., No.157.	...
1929	*Soils of the Bombay Presidency.*	D. L. SAHASRABUDDHE	*Bull. Dept. Agri.*, Bom., No.160.	...
1929	*Chemical Study of buffalo milk-casein.*	D. L. SAHASRABUDDHE & R. B. GODE	*J. Cen. Bur. Ani. Hus. & Dairying in Ind.* April & July issues.	...
1929	*Characterisation of very small quantities of proteins by Van Slyke's method.*	N. NARAYANA & M. SREENIVASAYA	*J. I. I. S.*	I. I. S.
1929	*The Determination of Pyruvic Acid.*	B. HANUMANTHA RAO KRISHNA & M. SREENIVASAYA	*J. I. I. S.*	I. I. S.
1929	*Contribution to the Study of Spike-Disease of Sandal (Santalum Album, Linn.). Part VI. Nitrogen Metabolism in healthy and spiked sandal leaves.*	N. NARASIMHAMURTHY & M. SREENIVASAYA	*J. I. I. S.*	I. I. S.

1929	*Enzymes from the Seeds of Cæsalpina Bonducella.*	V. N. PATWARDHAN	*J. I. I. S.*	I. I. S.
1929	*Amylase from zea mais.*	V. N. PATWARDHAN	*J. I. I. S.*	I. I. S.
1929	*Contribution to the Study of Spike-Disease of Sandal (Santalum Album, Linn.). Part VII. Factors influencing Diastatic Activity.*	B. N. SASTRI & M. SREENIVASAYA	*J. I. I. S.*	I. I. S.
1929	*Contribution to the Study of Spike-Disease of Sandal (Santalum Album, Linn). Part VIII. Chemical Composition of Tissue Fluids from the leaf.*	M. SREENIVASAYA & B. N. SASTRI	*J. I. I. S.*	I. I. S.
1929	*Contribution to the Study of Spike-Disease of Sandal (Santalum Album, Linn.). Part IX. Chemical Composition of Tissue Fluid from the Stem.*	M. SREENIVASAYA & B. N. SASTRI	*J. I. I. S.*	I. I. S.
1929	*Note on Starch liquefying action of Sandal Leaf Extracts.*	B. N. SASTRI	*J. I. I. S.*	I. I. S.
1929	*Studies in Silicic Acid Gels: Part I. The Time of Setting of Gels.*	MATA PRASAD & R. R. HATTIANGADI	*J. I. C. S.*, 6, 653, 1929.	R. I. S.
1929	*Studies in Silicic Acid Gels: Part II. The Hydrogen Ion Concentration and Cataphorism of the Gel-forming Mixtures.*	MATA PRASAD & R. R. HATTIANGADI	*J. I. C. S.*, 6, 893, 1929.	R. I. S.
1929	*Studies in Silicic Acid Gels: Part III. Effect of Non-electrolytes on the Time of Setting of the Gel-forming Mixtures.*	MATA PRASAD & R. R. HATTIANGADI	*J. I. C. S.*, 6, 991, 1929.	R. I. S.

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1929	*The Electrical Conductivities of Liquid Alkali-metal Amalgams.*	D. BOOHARIWALA, G. R. PARANJPE & MATA PRASAD	*Ind. J. Phys.*, *4*, 147, 1929.	R. I. S.
1929	*Studies in Coumarin Condensations—the Condensation of allyl acetoacetic ester with phenols.*	K. G. NAIK, R. D. DESAI & H. R. DESAI	*J. I. C. S.*	B. C.
1929	*Phosphorus Oxychloride as a condensing agent in the synthesis of coumarine derivatives.*	K. G. NAIK, R. D. DESAI & R. K. TRIVEDI	*J. I. C. S.*	B. C.
930	*Geometrical Inversion in Light.*	B. K. VAIDYA	*Proc. Roy. Soc.*	Liv. Uni.
1930	*Buthus Alticola Pocock.*	J. F. CAIUS	*Jour. Bomb. Nat. Hist. Soc.*, XXXIV, 3.	X. C.
1930	*Earth-eating and Salt-licking in India. Analyses IV-VII.*	J. F. CAIUS & K. S. MHASKAR	*Jour. Bomb. Nat. Hist. Soc.*, XXXIV, 1.	Pharm. Lab., Parel.
1930	*A Study of Indian Medicinal plants. II Gymnema Sylvestre, Br.*	K. S. MHASKAR & J. F. CAIUS	*Ind. Med. Research Memoirs*, Memoir No. 16.	Pharm. Lab., Parel.
1030	*A Comparative Study of the dried Barks of the commoner Indian Species of Genus Terminalia. Linn.*	J. F. CAIUS, K. S. MHASKAR & M. ISAACS	*Ind. Med. Research Memoirs*, Memoir No. 1 6.	Pharm. Lab., Parel.
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1930	*Velocity of Reaction in Mixed Solvents. Part II. The Velocity of Reaction between Sodium Thiosulphate and Alkyl Iodides in Organic Solvents—water mixtures.*	MATA PRASAD & R. D. GODBOLE	*J. I. C. S.*, *7*, 127, 1930,	R. I. S.
1930	*Studies in Silicic Acid Gels. Part IV Effect of Electrolytes on the Time of Setting of the Gel-forming Mixtures.*	MATA PRASAD & R. R. HATTIANGADI	*J. I. C. S.*, *7*, 341, 1930.	R. I. S.
1930	*Aqueous Solutions of Sodium Aluminates. Part I. Electrical Conductivity.*	MATA PRASAD, S. M. MEHTA & N. G JOSHI	*J. I. C. S.*, *7*, 973, 1930.	R. I. S.
1930	*An X-Ray Investigation of the Crystals of Azo-benzene.*	MATA PRASAD	*Phil. Mag.*, *10*, 306, 1930.	R. I. S. & Davy F Lab.
1930	*Condensation of Ethyl Acetoacetate with Aromatic Amines. Part I.*	G. V. JADHAV	*J. I. C. S.*	R. I. S.
1930	*Derivatives of Salicylic Acid. Part III. Synthesis of 3-sulpho salicylic acid.*	N. W. HIRWE	*J. I. C. S.*	R. I. S.
1930	*Derivatives of Salicylic Acid, Part II.*	A. N. MELDRUM & N. W. HIRWE	*J. I. C. S.*	R. I. S.
1930	*4-sulpho-3-hydroxy benzoic acid.*	M. S. SHAH	*J. C. S.*	M. R. S. I. G. C.

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1930	*Esterification in Mixed Solvents.*	B. W. BHIDE	*J. I. C. S.*	S. P. C.
1930	*Velocity of Reaction in Mixed Solvents. Part I. The Velocity of Reaction between Potassium persulphate and Potassium Iodide in Organic Solvent—water mixtures.*	MATA PRASAD, C. L. MANKODI & R. D. GODBOLE	*J. I. C. S.*	R. I. S.
1930	*Cattle Feeds of Western India.*	D. L. SAHASRABUDDHE	12 *Bull. Dept. Agri.*, Bom., No.161	...
1930	*Some sulphur derivatives of 2-methoxy toluene.*	KOLHATKAR & BOKIL	*J. I. C. S.*, VII, 843, 1930.	F. C.
1930	*The Kinetics of Coagulation.*	A. M. PATEL & B. N. DESAI	*Trans. Faraday Soc.*, Vol. 26, 130, 1930.	W. C.
1930	*Effect of Non-electrolytes on the Precipitation of Thorium Hydroxide from its salt solution in presence of alkali.*	A. M. PATEL & B. N. DESAI	*J. I. C. S.*, Vol. 7, 161, 1930.	W. C.
1933	*On the Influence of non-electrolytes on Colloidal thorium hydroxide with the progress of dialysis of the latter in the presence and absence of electrolytes.*	A. M. PATEL & B. N. DESAI	*Kolloid-Z.*, Vol. 51, 318, 1930.	W. C.
1930	*Interaction of chloro-sulphonic acid with substituted amides of Malonic and Methyl-malonic acids.*	K. G. NAIK & C. H. SHAH	*J. I. C. S.*	B. C.

1930	*A Study of the Interaction of Selenium-tetrachloride with substances containing the reactive methylene group.*	K. G. NAIK & R. K. TRIVEDI	*J. I. C. S.*	B. C.
1930	*A Study of the Interaction between Thionyl chloride and substances containing the reactive methylene group. Part I. The Formation of Sulphoxides.*	K. G. NAIK, R. D. DESAI & M. M. PAREKH	*J. I. C. S.*	B. C.
1930	*A Study of the Interaction between Thionyl chloride and substances containing the reactive methylene group. Part II. Formation of Sulphides.*	K. G. NAIK & M. M. PAREKH	*J. I. C. S.*	B. C.
1930	*Interaction of Iodine-monochloride with substances containing the reactive methylene group.*	K. G. NAIK & C. C. SHAH	*J. I. C. S.*	B. C.
1930	*Mercuration of substances containing the reactivc methylene group.*	K. G. NAIK & C. C. SHAH	*J. I. C. S.*	B. C.
1930	*Petrol-water Emulsions.*	C. VARADHAN & H. E. WATSON	*J. I. I. S.*	I. I. S.
1930	*Studies in Dextrins. Part I. Action of Amylase from cholam (Surghum Vulgare) on potato-starch.*	V. N. PATWARDHAN	*J. I. I. S.*	I. I. S.
1930	*Studies in Dextrins, Part II. Amylase from Ragi (Elensine coracana)*	V. N. PATWARDHAN & N. NARAYANA	*J. I. I. S.*	I. I. S.
1930	*Dilatometric Studies in Enzyme Action.*	M. SREENIVASAYA & B. N. SASTRI	*J. I. I. S.*	I. I. S.

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1930	*(1) Power Alcohol and paper from Rice Straw.* *(2) Estimation of Pentoses and Pentosans by different methods.*	D. D. DESHPANDE	*J. I. I. S.*	I. I. S.
1930	*The Physical Properties of pure Triglycerides.*	R. B. JOGLEKAR & H. E. WATSON	*J. I. I. S.*	I. I. S.
1930	*The Preparation and Properties of α-monoglycerides.*	R. D. REWADIKAR & H. E. WATSON	*J. I. I. S.*	I. I. S.
1930	*Amylase from Wheat*	D. V. KARMARKAR & V. N. PATWARDHAN	*J. I. I. S.*	I. I. S.
1930	*The spike-disease of Dodonaea Viscosa.*	B N. SASTRI & N. NARAYANA	*J. I. I. S.*	I. I. S.
1930	*Studies in the Proteins of Indian Foodstuffs. Part III. The Globulins of Bengal Gram (Cicer Arietinum, Linn) and Horse Gram (Dolichos Biflorus)*	N. NARAYANA	*J. I. I. S.*	I. I. S.
1930	*Biochemistry of Tan-Liquor Fermentation.*	P. D. DALVI	*J. I. I. S.*	I. I. S.
1930	*Note on the Estimation of Tannic and Gallic Acids.*	P. D. DALVI	*J. I. I. S.*	I. I. S.
1931	*The Interaction between Iodine Pentoxide and Nitric Oxide*	M. S. SHAH & T. M. OZA	*J. C. S.*	M. R. S. I. G. C.

1931	*A synthesis of 5-hydroxy-2-methoxy benzoic acid.*	A. N. MELDRUM & M. S. SHAH	*J. I. C. S.*	M. R. S. I. G. C.
1931	*Embelin.*	K. S. NARGUND & B. W. BHIDE	*J. I. C. S.*	M. R. S. I. G. C. & S. P. C.
1931	*An X-Ray Investigation of the Crystals of Copper Formate Dihydrate.*	MATA PRASAD & H. M MAPARA	*Ind. J. Phys.*, 6, 41, 1931.	R. I. S.
1931	*Preparation and Properties of Nickelous Oxide.*	MATA PRASAD & M. G. TENDULKAR	*J. C. S.*, 1403, 1931.	R. I. S.
1931	*The Action of Sulphuric Acid on Nickel Copper Matte.*	MATA PRASAD & M. G. TENDULKAR	*J. C. S.*, 1407, 1931.	R. I. S.
1931	*The Photo-reduction of Alcoholic solutions of Ferric Chloride.*	MATA PRASAD & N. V. SOHONI	*J I C. S.*, 8, 189, 1931.	R. I. S.
1931	*Condensation of Ethyl propyl acetoacetate with Aromatic amines. Part I.*	G. V. JADHAV	*J. I. C. S.*	R. I. S.
1931	*The structure of glutaconic acids and esters. Part I. Cyanoglutaconic esters.*	G. A. KON & H. R. NANJI	*J. C. S.*	Imp. Coll. Sc. Tech.
1931	*Investigations on hyponitrics. Part I. Sodium Hyponitrites, preparation and properties.*	J. R. PARTINGTON & C. C. SHAH	*J. C. S.*	Arms. Coll. Durh. Uni.
1931	*The Analysis of Mixtures of Hydrogen, Methane and Ethane.*	O. J. WALKER & S. N. SHUKLA	*J. C. S.*	Uni. Coll. Exeter.
1931	*Studies in the Naphthalene Series. Part III. The Preparation of 3-amino-2-naphthyl Methyl Ether.*	G. B. JAMBUSERVALA, SIDNEY HOLT & F. A. MASON	*J. C S.*	Coll. Tech., Manch.

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1931	*The Chemistry of alkylcyclopentanones. Part I. Derivatives of 3-methylcyclopentanone.*	R. D. DESAI	*J. C. S.*	Imp. Coll. Sc. Tech.
1931	*Condensation of Acetone-di-Carboxylic Acid with Phenols and Phenolic Ethers, Part I. Formation of β-substituted Glutaconic Acids.*	D. B. LIMAYE & V. M. BHAVE	*J. I. C. S.*	R. I. E. I.
1931	*Condensation of Phenols and Phenolic Ethers with Acetone dicarboxylic Acid. Part I. β-substituted Glutaconic Acids.*	V. M. DIXIT	*J. I. C. S.*	R. I. S.
1931	*The Condensation of Chloral with m-cresotic Acid.*	N. M. SHAH & R. L. ALIMCHANDANI	*J. I. C. S.*	K. C.
1931	*The Mechanism of the Oxidation of Laudanosine.*	BHAGWAT, MOORE & PYMAN	*J. C. S.*	Coll. Tech. Manch.
1931	*Nitrogen Recuperation in the Soils of the Bombay Presidency, Part II.*	D. L. SAHASRABUDDHE & B. H. GHATIKAR	*Ind. Jour. Agri. Sc.*, Vol. I, Part VI.	...
1931	*Decomposition of Phenol and Naphthol Ethers by means of Concentrated Hydrochloric Acid.*	KOLHATKAR & GHASWALLA	*J. I. C. S.*, VIII, 511, 1931.	F. C.
1931	*Condition of Silver Chromate in Gelatine hydrolysed and electro-dialysed to different extents.*	G. M. NABAR, & B. N. DESAI	*Nature*, Vol. 127, 628, 1931.	W. C.

1931	*Relation between Charge and Stability of Colloidal Gold.*	G. M. NABAR & B. N. DESAI	*Nature*, Vol. *127*, 666, 1931.	W. C.
1931	*Condition of sparingly soluble substances in Gelatine.*	B. N. DESAI	*Nature*, Vol. *128*, 222, 1931.	W. C.
1931	*Coagulation of Colloids by Electrolytes.*	B. N. DESAI & P. M. BARVE	*Nature*, Vol. *128*, 907, 1931.	W. C.
1931	*Studies in the Influence of non-electrolytes containing different number of hydroxy groups on the precipitation of thorium hydroxide from solution of thorium nitrate on the addition of NaOH.*	G. M NABAR, A. M. PATEL & B. N. DESAI	*Kolloid-Z*, Vol. *52*, 173, 1931.	W. C.
1931	*Interaction of Sulphuryl chloride with substances containing the reactive methylene group, Part II.*	K. G. NAIK & N. T. TALATI	*J. I. C. S.*	B. C.
1931	*Mercury acetamide as a mercurating agent.*	K. G. NAIK & L. D. SHAH	*J. I. C. S.*	B. C.
1931	*Interaction of metallic sodium with substances containing the reactive methylene group.*	K. G. NAIK & L. D. SHAH	*J. I. C. S.*	B. C.
1931	*The Action of Hydrogen Sulphide on Chromates Hydrogen Chromate.*	H. B. DUNNICLIFF & G. S. KOTWANI	*Jour. Phys. Chem.* Vol. XXV, No. 11.	G. C. L. & D. J. S. C.
1931	*Cantharidine from Mylabus Pustulata Fb. India.*	B. H. IYER & P. C. GUHA	*J. I. I. S.*	I. I. S.
1931	*The Fatty Acids from Oil of Cantharis.*	B. H. IYER &. P. R. AYYAR	*J. I. I. S.*	I. I. S.

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1931	*Amylase from Rice. Dialysis of some Cereal Amylases.*	V. N. PATWARDHAN & D. V. KARMARKAR	*J. I. I. S.*	I. I. S.
1931	*Studies on the Chemical Composition and Physical properties of Plant Tissue Fluids. I. Effect of Age and Environment on the Tissue Fluids of French beans (Phaseolus Vulgaris).*	C. N. ACHARYA & B. N. SASTRI	*J. I. I. S.*	I. I. S.
1931	*Study in Electro-Culture. Part I.*	K. V. GIRI, T. J. MIRCHANDANI & V. SUBRAHMANYAN	*J. I. I. S.*	I. I. S.
1931	*The Reactivity of Dimethyldihydroresocin, Part II. Behaviour towards orthonitro and Ortho-Amino-benzaldehydes.*	B. H. IYER & G. C. CHAKRAVARTI	*J. I. I. S*	I. I. S.
1932	*On the Theory of Equations of States.*	T. S. WHEELER	*Phil. Mag.*	R. I. S.
1932	*The Theory of Thermal Decomposition of Methane.*	T. S. WHEELER	*Rec. Trav. Chim.*	R. I. S.
1932	*Calculations of the Space Displacement of Terminal Carbon atoms in ring formation.*	T. S. WHEELER & K. R. GUNJIKAR	*J. I. C. S.*	R. I. S.
1932	*Condensation of butyl chloral with Gallic Acid and the three Cresotic Acids.*	A. N. MELDRUM & Miss B. N. KATRAK	*J. I. C. S.*	R. I. S.

1932	*The Decomposition of Ammonium Nitrate.*	M. S. SHAH & T. M. OZA	*J. C. S.*	M. R. S. I. G. C.
1932	*Über Synthesen in der Furo-Cumarin-Gruppe, I Mittl. Buildungeines 3·4 Dimethyl Furocumarins.*	D. B. LIMAYE	*Ber.*	Ras. Nid. Kap.
1932	*Condensation of benzanilides with p-dialkyl anilines with phosphoryl chloride as condensing agent and the mechanism of reaction.*	R. C. SHAH, R. K. DESHPANDE & J. J. CHAUBAL	*J. C. S.*	R. I. S.
1932	*A new and direct synthesis of p-dialkyl-aminobenzo-phenomenon.*	R. C. SHAH & J. J. CHAUBAL	*J. C. S.*	R. I. S.
1932	*An X-Ray Investigation of the Crystals of Ortho Azotoluene.*	MATA PRASAD & K. V. DESAI	*Phil. Mag.*, *13*, 600, 1932	R. I. S.
1932	*Extinction Coefficients of the Silicic Acid Gel-forming Mixtures.*	MATA PRASAD, S. M. MEHTA & J. B. DESAI	*Jour. Phys. Chem.*, *36*, 1324, 1932.	R. I. S.
1932	*Viscosity of the Silicic Acid Gel-forming Mixtures.*	MATA PRASAD, S. M. MEHTA & J. B. DESAI	*Jour. Phys. Chem.*, *36*. 1384, 1932.	R. I. S.
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1932	*A Physical Method of estimating Ferrous and Ferric Ion formed by the Action of Potassium Dichromate and Potassium Permanganate upon Ferrous Salts.*	MATA PRASAD & R. Y. DESHPANDE	*J. I. C. S.*, *9*, 113, 1932	R. I. S.
1932	*A note on the liesegang rings of Silver Chromate in gelatin.*	B. N. DESAI & G. M. NABAR	*J. I. C. S.*, Vol. *9*, 141, 1932	W. C.

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1932	*The influence of hydrolysed gelatine on the precipitation of silver chromate.*	B. N. DESAI & G. M. NABAR	*Trans. Faraday Soc.*, Vol. *28*, 449, 1932	W. C.
1932	*A Study of Interaction between Thionyl Chloride and substances containing the reactive methylene group, Part III.*	K. G. NAIK & V. B. THOSAR	*J. I. C. S.*	B. C.
1932	*Mercuration of Compounds containing the reactive methylene group by means of mecuric acetate.*	K. G. NAIK & R. P. PATEL	*J. I. C. S.*	B. C.
1932	*A study of Liquid-liquid junctions with a view to eliminate the potential difference thereat.*	J. V. LAKHANI	*J. C. S.*	Edin. Uni.
1932	*The formation and stability of Spiro-compounds. Part XIV. The Effects of the Methylcyclohexane Ring on the Carbon Tetrahedral Angle.*	R. D. DESAI	*J. C. S.*	Imp. Coll. Sc. & Tech. Lond.
1932	*The Chemistry alkylcyclopentanones Part II. The Effect of the methylcyclopentane ring on the Carbon tetrahedral angle.*	R. D. DESAI	*J. C. S.*	Imp. Coll. Sc. & Tech. Lond.
1932	*Dihydroresorcinols Part I. The Alkylation of Substituted Dihydroresorcinols.*	R. D. DESAI	*J. C. S.*	Imp. Coll. Sc. & Tech., Lond.
1932	*Investigations on Alkylaconitic Acids.*	R. D. DESAI	*J. C. S.*	Imp. Coll. Sc. & Tech., Lond.

1932	*Salt Stains on South Indian Hides and Skins.*	V. N. PATWARDHAN & M. S. SASTRY	*J. I. I. S.*	I. I. S.
1932	*Chemical Examination of the root-bark of Plumbago Rosea, Linn.*	M. C. TUMMIN KATTI &. V. N. PATWARDHAN	*J. I. I. S.*	I. I. S.
1932	*Aryl Di-and Poly-Stibinic Acids, Distibinous Oxides and Distibino-Compounds.*	SORAB M. MISTRY & P. C. GUHA	*J. I. I. S.*	I. I. S.

Obituary

Sir Dorab J. Tata

The death of Sir Dorab J. Tata which took place in Germany on the 3rd June 1932 at the age of 73 has removed from our midst one of the greatest industrialists of our country. The dominant note of Sir Dorab Tata's life was filial piety. The establishment and development of the great iron and steel works at Jamshedpur, the hydro-electric installations on the Western Ghauts which have transformed the industrial conditions of Bombay, the big cotton mills and last, though not the least, the Bangalore Research Institute, were due to the filial piety with which he pursued and the singleness of purpose with which he devoted himself—in face of many disappointments and delays—to the execution of the far-sighted designs and bold projects of his father Jamshedji Nasarwanji Tata. It is impossible to write anything about Sir Dorabji Tata without at the same time referring to the work of his illustrious father Jamshedji, for the bold conceptions, high ideals and the breadth of vision of the father were given a practical shape by the no less enterprising spirit, dogged will, and unbounded patience and perseverance of the son. The example which both father and son have set to our industrialists and capitalists of organisation, efficiency and thoroughness is unique and will ever act as a beacon light to the future captains of industry. The noble examples which Sir Dorab has, again, set of probity and honesty in business, of holding aloof from speculation and of holding high the interests of the shareholders are precious legacies which he has left to our countrymen. Sir Dorabji also refrained like his father, on principle, from taking part in politics. Both father and son studied how great industrial concerns were founded in the Western countries and run successfully. They found out that great technical and scientific institutions should precede the establishment of great industries. Hence it was that Mr. Jamshedji Tata conceived of, and Sir Dorabji executed, within a few years of his father's death, the big scheme of the Research Institute whose aim, according to them, was not to turn out a few indifferent chemists and electrical engineers but principally to be a centre of research and a training ground for students in methods of research and a nursery for fostering the spirit of research. The great lesson which the Tatas have taught to our industrialists is that science should serve as a handmaid to industry, that the latest discoveries in science should be

THE LATE SIR DORAB J TATA

utilised in industry, that science and industry are so closely interdependent that it is only on the mutual and salutary co-operation of them that an industry may expect to rise to the highest position of eminence. These principles are exemplified in every undertaking of the firm of Tata, be it the great iron and steel industry at Jamshedpur, or the hydro-electric power schemes on the Western Ghauts.

One of the most prominent characteristics of the father and the son was their great love for the land of their birth. Mr. Jamshedji had, again, a powerful vivid imagination which presented to him a picture of India as a country of vast natural resources, a country capable of great industrial development. He was a rare combination of a man of great ideas and a man of action. It was this which made him conceive of the two gigantic projects, *viz.* the Iron and Steel industry and the hydro-electric schemes. But before he could carry out these schemes he passed away and the herculean task of executing the bold schemes of the father fell on Sir Dorab Tata and his younger brother Sir Ratan Tata. Within ten years of his death all the three great schemes came into existence, the two above-mentioned and that of the Indian Institute of Science at Bangalore. Both the great industrial enterprises have proved successful beyond the most sanguine expectations of their founders. We have seen what they have been able to achieve so far both in times of peace and war but what they are capable of achieving in the future we can only dimly realize. The Iron and Steel Industry at Jamshedpur is an enterprise of a monumental character and would no doubt form a turning point in the transition of India from a great agricultural country into a manufacturing country. No body dreamt that soon after the completion of the great undertaking an opportunity would arise by which this infant industry would be able to render a national and imperial service by helping the armies of the Empire in the Eastern theatres of the war by a ready supply of rails and shell steel.

The story of Sir Dorabji's prospecting work, sometimes for months together in the jungles of the Central Provinces and Orissa, and his discovery along with his cousin Mr. Shapurji Saklatwalla and Mr. Weld, an American expert, of an iron hill of almost solid metal, yielding 65·5% of pure iron near a village called Sakchi are a romance of modern industry. The richness of the deposits constituted, according to the experts, one of the mineral wonders of the world.

I cannot conclude this short sketch without referring to the benefactions the Tata family made for the encouragement of literary and scientific research. The Tata Foreign Scholarship Fund, the princely gift of Rs. 30 lakhs for the Bangalore Research Institute, the endowment of a chair of Sanskrit at the Bhandarkar Institute at Poona, the subsidising of the researches of many a scholar, particularly those who desired to throw further light upon the history of the Parsis, the gift of £25,000 to the University of Cambridge for equipping the laboratories of the School of Engineering, all show that the charities of Mr. Jamshedji Tata and his two illustrious sons were cosmopolitan, but they sink into insignificance when we consider the trust deed which Sir Dorab executed only a couple of months before he passed away, covering property worth over three crores of rupees to be used for the amelioration of humanity without distinction of race or creed. Over and above this he has set aside a sum of Rs. 25 lakhs for research in connection with what are known as incurable diseases, particularly the malignant type of anaemia of which his wife died a year ago. These examples show that Sir Dorabji Tata knew not only how to produce wealth but also how to use and distribute it. He was indeed a great industrialist, philanthropist, patron of art and learning as also a great sportsman. India can ill afford to lose such a man and the gap which his death has created in the industrial world will be very difficult to fill.

D. D. K.

Notes and News

It was refreshing to note the great emphasis laid by Sir C. V, Raman in the inspiring Convocation address which he gave to the newly admitted graduates of the Bombay University on the study of science. He pointed out that the greatest enemy of true scholarship was scholasticism, that scholarship and scholasticism were worlds apart; that where scholasticism was in the ascendant undue importance was given to examinations, degrees etc. True scholarship went hand in hand with research, independence of thought and original thinking. The function of a University, he said, was the encouragement of true scholarship or in other words it was the encouragement of the human intellect and the human spirit in their highest manifestations. The greatest value of the study of science lies, not so much in the imparting of knowledge about natural phenomena and the laws of nature, as in the teaching of the *scientific method* which has served as a powerful weapon in the hands of man in the discovery of truth and which has given him to-day a new view of the universe he lives in. It was Bacon who emphasised the use of the scientific method in the discovery of truth. And this method which has played such an important part in the rapid growth of science is not the monopoly of the scientists alone. If the same method were used in the problems of daily life, be they political or industrial, social, educational or religious it would usher in a new era of progress and enlightenment in all the departments of life. In the courageous application of scientific knowledge and the enlightened use of the scientific method lies the material salvation of any country and of our country in particular which is so much caste-ridden and which is so very conservative, ignorant and superstitious.

As an illustration of the material service done by science may be cited the great Nitrogenous Products Industry which came into being following on the warning given by Sir William Crookes in his Presidential Address before the British Association for the advancement of Science in the year 1898. He said that considering the rate at which the existing sources of manures were depleted there would be a shortage of manure and consequently a wheat famine or an insufficiency of wheat crops in the near future if they were not supplemented by synthetic manures. The danger of a shortage of wheat crops was largely averted by the manufacture of synthetic manures which showed a high water mark of scientific and technical skill and efficiency. Little did Sir William Crookes dream then that the question of over-production would be a more difficult problem to solve and would loom more largely before the minds of people than the question of under-production and that it would be considered a cause of depression in trade (*Times of India*, 26-8-32) and a curse.

Is it indeed the curse of over-production or the tragedy of ill-distribution that over a thousand million pounds of coffee worth (theoretically) over £10,000,000 was recently destroyed by the orders of the National Coffee Council of Brazil either by dumping it into the Atlantic or converting it into fuel-bricks ? (*Illustrated London News*, 18-7-32). A few months back we read about the destruction of wheat and cotton crops because they were in plenty and all these three, coffee, wheat and cotton had to be destroyed in order to stabilize the prices ! Were they really in excess of the demand ? Are not the means of transportation very much better now than they were years ago ? Have not the different parts of the world come nearer to one another and have not time and space been considerably shortened owing to the great and rapid discoveries in Science and Engineering during the last 100 years ? How are these facts to be reconciled with the memorable statement that the man who made two blades of grass grow where one grew before was a benefactor of the human race ? What is the remedy ?

There is no doubt that the application of scientific knowledge will make not only two but half a dozen or a dozen blades of grass grow where one grew before, but if this increased production were not made available by right distribution to people who do not get even one full meal a day and who have not got even sufficient clothing to cover their bodies what is the use of this application of scientific knowledge which has been the result of untiring, unselfish labour, spread over many years, of a large number of scientists in different parts of the civilized world ? Science has no doubt both the power to produce and the power to distribute but there must be also a desire and a will to distribute. This once more brings to the forefront the problem of the Individual ; it is the individual who must change ; this change must come from within ; his inner attitude must change ; no amount of external change will bring us nearer to the solution of the present day world problems. Solve the problem of the individual and the world problems will automatically solve themselves.

How to bring about this change in the will of the individual is the most important question. What effect has science had on reforming the human will ? When we consider this side of science we cannot help being struck by the serious lag between the rapid scientific advance on the one hand and the stationary ethical position on the other,—a lag which has already found expression in the greatest tragedy of history and its after-effects,—a lag which is also responsible for the anomalies mentioned above. The same note has been struck by Sir Alfred Ewing, the 77-year-old President of the British Association, in his presidential address to the meeting of the Association held at York on the 3rd September 1932; expressing his grave doubts as to the fitness of man to use the gifts bestowed on him by scientists and inventors he said: "Man is ethically unprepared for the great bounty. In the slow evolution of morals he is still unfit for the tremendous responsibility it entails. The command of Nature has been put into his hands before he knows how to command himself." It is, therefore, the function of science and the scientific culture given by a University to see that this gap, which threatens the disruption of our civilisation, is closed up. In other words, science must henceforward include in its programme ways and means for the most effective drive towards ethical and spiritual values and thus render its most priceless human service. It is the urgent duty of every University to see that the advance of science and the spread of scientific culture proceed along a parallel advance in man's ethical and spiritual development. The alumni of our University will have to go forth not only as searchers after truth but also as devotees in the cause of the true religion of humanity. The motto of science should be not only Truth but TRUTH and SERVICE.

To summarise, the University should see that it gives every possible encouragement to true scholarship and research not only in science but in all branches of knowledge, that *every* alumnus of our Alma Mater is trained in, and made familiar with the scientific method and its use, whatever his subject, so that he could employ it in all problems of life, and last, though not the least, that every graduate and undergraduate of the University receives such a background in his training that he may be ready to share whatever he has got—knowledge, wealth, power and possessions—with others, of whatever race and country, who are deficient in them, and for the common good of all.

D. D. K.

Reviews

Plane Trigonometry. By B. B. BAGI, M. A. Price Rs. 3.

The book represents an attempt to make full use of the best methods available of teaching the subject. The ground covered is that required in F. Y. Arts and Inter Arts and Science classes. Hence it is an elementary book on Trigonometry. If the subject is to be taught in an intelligent way, long and laborious methods have to be avoided and the elegance of formulae and results emphasized. Prof. Bagi has been successful in this respect. The methods of projection have been employed throughout. The theory of orthogonal projection has been systematically given in Chapter III. The treatment of graphs of Trigonometrical functions is more thorough than that of some other text-books. The Chapter on "Use of Algebraic signs in Geometry" is comprehensive. The conventions of algebraic signs are carefully explained and interesting results are obtained on areas. The author has at some places gone beyond the syllabus prescribed. In order to create interest in the subject among the students, he has deduced many useful results; those on properties of quadrilaterals deserve to be specially noted. Such articles are marked with an asterisk.

The book is teeming with beautifully illustrated examples. Some examples given in the Miscellaneous set are clearly beyond the average standard of the Intermediate class. Thus the book has many good features. If the author had given a brief history of the subject or at least the names of persons to whom the results obtained in the book are generally attributed, the book would have certainly been more useful and interesting. The general appearance of the book is good.

Volumetric Analysis. By G. FOWLES, M. Sc., A. I. C. (G. Bell and Sons, Ltd. 1932.) Price 6*s.*

When one refers to the standard text-books of quantitative chemical analysis one usually finds that the material presented and the treatment given for various processes are far from being completely satisfactory in light of rapid advances made in chemical knowledge during the last ten to fifteen years. The students of chemistry often fail to get an up-to-date explanation regarding the reactions proceeding in acidimetry, alkalimetry, oxidation, reduction and precipitation processes. The author of this book has made a successful attempt to meet with such requirements of students in volumetric reactions. For instance, the *H*-ion concentration has been given the special consideration it deserves and employed as a basis of explanation in titrations of acids, basis, salts of strong acids and weak bases and *vice versa*. The theory of indicators and buffer solutions is described together with the *pH*. ranges within which the common useful indicators show the exact points of neutrality. Processes involving the use of oxidising and reducing agents are similarly discussed with the help of oxidation reduction potential and it is shown how one substance behaves as a stronger oxidising agent compared to another with respect to the same reducing agent. The treatment of precipitation reactions is also satisfactory and proper attention is paid to phenomena of adsorption solubility product and other relevant matters. On the whole the book is a very useful addition to the existing text-books on quantitative chemistry and with its help the students, instead of doing things mechanically, would acquire the habit of following sound theoretical reasoning in their experimental work.

M. S. S.

Modern Methods in Quantitative Chemical Analysis. By A. D. MITCHELL, D.Sc., F.I.C., and A.M. WARD, Ph. D., D. Sc., A. I. C., (Longmans, Green and Co., Ltd. 1932). Price 6*s*.

The authors of this book have supplied a very useful compilation of selected and accurate methods in quantitative chemical analysis of certain elements, radicals and compounds which have been lately published and which have not been so far included in standard textbooks of analytical chemistry. A great majority of processes have been worked out under specified conditions and modifications have been introduced by the authors wherever necessary to secure greater accuracy. The book will serve as an important supplement to standard works on quantitative chemical analysis and will be of great value to advanced as well as research students as a reference book in the selection of up-to-date methods needed in their work.

M. S. S.

Exchanges and Acknowledgments

EXCHANGES:

Anthropos: Internationale Zeitschrift fur Volker-und Sprachenkunde—Revue Internationale d'Ethnologie et de Linguistique. Wien, Austria.

Dacca University Journal.

Drama: published by the British Drama League, Adelphi Terrace, London.

Empire Cotton Growing Review: Published by Empire Cotton Growing Corporation, London.

Epigraphia Indica: Published by the Government Epigraphist for India.

Indian Historical Quarterly: edited by Dr. Narendra Nath Law, and published at Calcutta.

International Cotton Bulletin: published by the International Federation of Master Cotton Spinners' and Manufacturers' Association, Manchester, England.

Journal of Indian History, edited by Dr. S. Krishnaswami Aiyangar, Madras.

Journal of the Annamalai University.

Journal of the Faculty of Science, Hokkaido Imperial University, Sapporo, Japan.

Journal of the University of Madras.

Labour Gazette, published by the Labour Office, Secretariat, Bombay.

Natural History: Magazine of the American Museum of Natural History, 77th Street and Central Park West, New York City, U.S.A.

Publications of the Bureau of Economic and Social Research, Sun-Yatsen University, Canton, China.

Review of the Academy of Philosophy and Religion, Poona, India.

The Servant of India, (Poona, India).

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Radiobiologia: Archivio Internazionale: Anno 1—Vol. I—Fasc. 1 April 1932. (San Gregorio, 173, Venezia, Italia).

Memoirs of the Faculty of Science and Agriculture, Taihoku Imperial University, Formosa, Japan, Vol. V, No. 3, and Vol. VI, No. 1, July, 1932.

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Journal
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VOL. I MARCH 1933 PART V

THE USE OF SEX-DENOTING TERMS IN THE DESCRIPTION OF SPOROPHYTES

By

D. L. DIXIT, B. A.
Fergusson College, Poona.

Such terms as 'Male' 'Female' 'Neuter' 'Unisexual' 'Bisexual' 'Hermaphrodite' etc. are often used in Botanical literature in the description of plants belonging to the Sporophyte generation. But in this generation the organisms are known to produce spores (asexual cells) only, they never produce sexual cells. While the gametophyte aspect of an organism is alone concerned in the production of sexual cells; and such a kind of Gametophyte is present in flowering plants. Naturally, therefore, sex-denoting terms can be used in the description of the Gametophyte and not certainly in the Sporophyte.

The old terminology was based upon the now disproved view that the stamens and carpels are male and female organs and consequently it ought to give place to an altogether new terminology which will be consistent with facts in Nature. But the old practice has not yet been given up: nay attempts are even made to find out sexuality in the flowering plants. I shall take a brief survey of the different views advanced in favour of retaining the old terms; and then give my own views about the effects produced by the faulty nomenclature.

It is argued by some that the reproductive cells in flowering plants have been looked upon as sexual cells by good many old writers and any good English Dictionary will also give the same meaning. The Pollen grain for instance has been described as the male element in any Dictionary. Now if the reproductive cells are male or female what harm is there to call the plant and flowers (possessing those reproductive cells) as male or female?

male plant, while we call a plant or a flower as female, if it possesses the embryo-sac-cell, because the latter produces the female gametophyte (the real female plant).

This line of argumentation will lead us to believe that Fern, Lycopodium etc. are bisexual because the prothalli that are produced after the germination of their spores, are hermaphrodite, or that Equisetum is unisexual because its spores produce unisexual prothalli. I think nothing can be more illogical.

(2) My second argument against such a kind of conventional meaning is that it is likely to create confusion with regard to the use of the terms. The terms, Male, Female, Neuter etc. are already very definite in their usual connotation, expressing as they do some very definite conditions in sexuality; but by the conventional meaning they will show other conditions in asexuality differing from the former in their very basic ideas. The use of the same terms to express two very widely differing conditions in sexuality and asexuality is in itself very confounding and unscientific. Such a kind of ambiguity in scientific language should be discouraged.

(3) Even if we allow such a kind of conventional meaning for the present, it is not possible to retain the same for all time to come. The terms are so often used in their usual sense in our every day life, that this usual meaning alone will present itself to many minds and the conventional meaning will soon be forgotten. Besides, there is no criterion by means of which one can distinguish the conventional meaning from the usual one. The female plant in Cycas, for instance, may mean the sporophyte or the Gametophyte, and one cannot definitely say in what sense the word has been used. The sporophyte Cycas which bears the ovuliferous leaves will be recognised as the female plant by convention while the real female plant is the endosperm tissue produced by the embryo-sac cell and bearing the archegonia. Out of these two, the real female plant will be forgotten on account of its microscopic nature and the sporophyte alone will be remembered as the female Cycas as is done even at present.

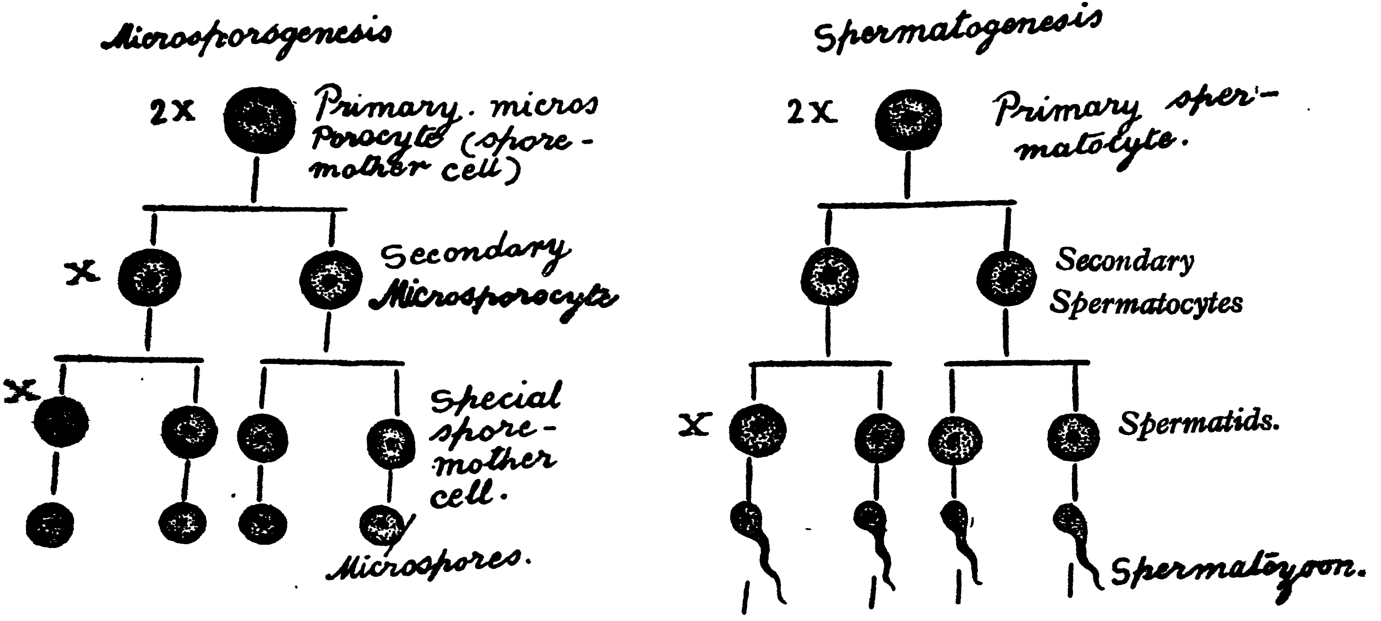
We have so far seen that it is not convenient to retain the terms male, female etc. simply because they are old or because some conventional meaning might be put upon them.

III. The use of the terms is however defended by some on cytological grounds. In their opinion the sporophyte plant is a diploid individual like animals and if animals are male or female, we can as well call plants male or female.

This argument appears to be of some importance no doubt; but better considerations show that it won't stand the test of reason. For it is rather the nature of the reproductive cells, that an organism gives rise to, that ought to determine its sexuality or non-sexuality; its haploid and diploid stages count but very little in this consideration. They simply express the one to two (1:2) ratio exhibited by the number of chromosomes found in the sexual and asexual generations. Sexual and asexual generations were recognised long before the the haploid and diploid natures were determined and it has been found that sexual organisms are haploid and asexual ones are diploid in their usual routine. But all haploids are not sexual nor are all diploids asexual. The phenomena of apospory and apogamy will bear me out in this respect. The haploid prothallus of Fern is known to give rise to the Fern plant vegetatively; here it is the haploid Fern plant that is asexual. A part of the stalk of the diploid capsule of Moss was induced to produce vegetatively the moss plant—a diploid sexual individual. The sexual cells of this plant were of course diploid and the asexual sporophyte in the form of the sporogonium, that was produced from the united diploid gametes was tetraploid. The stalk of this tetraploid capsule was again induced to produce sexual moss plant vegetatively so that this moss plant was tetraploid. Here we get haploid, diploid and tetraploid kinds of mosses all of which are sexual. In the life's cycle, the haploid moss plant and the diploid capsule will alone enter; we shall not get the diploid moss plant alternating with the diploid capsule nor the haploid moss plant alternating with the tetraploid capsule; in the same way the diploid moss plant will alternate with the tetraploid capsule while the tetraploid moss plant will alternate with the octaploid capsule. Thus sexuality or non-sexuality does not depend upon haploid or diploid stages; a haploid Fern can be asexual, while a diploid or tetraploid moss plant can be sexual. But even in these cases, exceptional as they appear to be, the usual ratio of one to two (1:2), that the number of chromosomes of the sexual plant bears to the number of chromosomes of the asexual one, is very faithfully kept up; so that the sexual generation as a rule bears half the number of chromosomes that are found in the asexual plant. Thus two distinct haploid and diploid stages are prominently observed in the case of plants in general.

The evolutionary history of animals on the other hand reveals quite a different condition in their life cycle. If alternation of generations is a rule in plant life, it is an exception in animal life, only a few of the lower organisms being able to exhibit it. Consequently almost

FIG. 1.


Microsporogenesis
2X
Primary. micros Porocyte (spore-mother cell)
X
Secondary Microsporocyte
X
Special spore-mother cell.
Microspores.
Spermatogenesis
2X
Primary sper-matocyte.
Secondary Spermatocytes
X
Spermatids.
Spermatozoon.

all animals are diploid, there is no haploid stage. There is also another important difference between plants and animals in this respect. Both the haploid and the diploid individuals in plants produce haploid reproductive cells; but these reproductive cells behave differently in both these cases. The haploid reproductive cells produced by the haploid individual, are sexual cells (*i. e.* they cannot reproduce by themselves, but when two such cells unite, it is only this United cell that is capable of giving rise to a new individual). On the other hand the haploid reproductive cells produced by the diploid individual are asexual cells (*i. e.* they can by themselves produce a new individual). Thus in the case of plants two types of haploid cells are produced—sexual as well as asexual.

Now in the case of animals the asexual reproductive cells and the haploid sexual individuals are not produced at all. There are only the haploid sexual cells produced from the diploid individual. Thus if the diploid individual in plants produces haploid asexual cells, the diploid individual in animals produces the haploid sexual cells.

It is however to be noted that sporogenesis in plants is carried on almost identical lines with gametogenesis in animals; Microsporogenesis being comparable to spermatogenesis and megasporogenesis to Oogenesis. Figures 1 and 2 (on pp. 6 and 8) will illustrate what I mean.

Both the primary microsporocyte and the primary spermatocyte are diploid while in both cases the reproductive cells formed, are haploid.

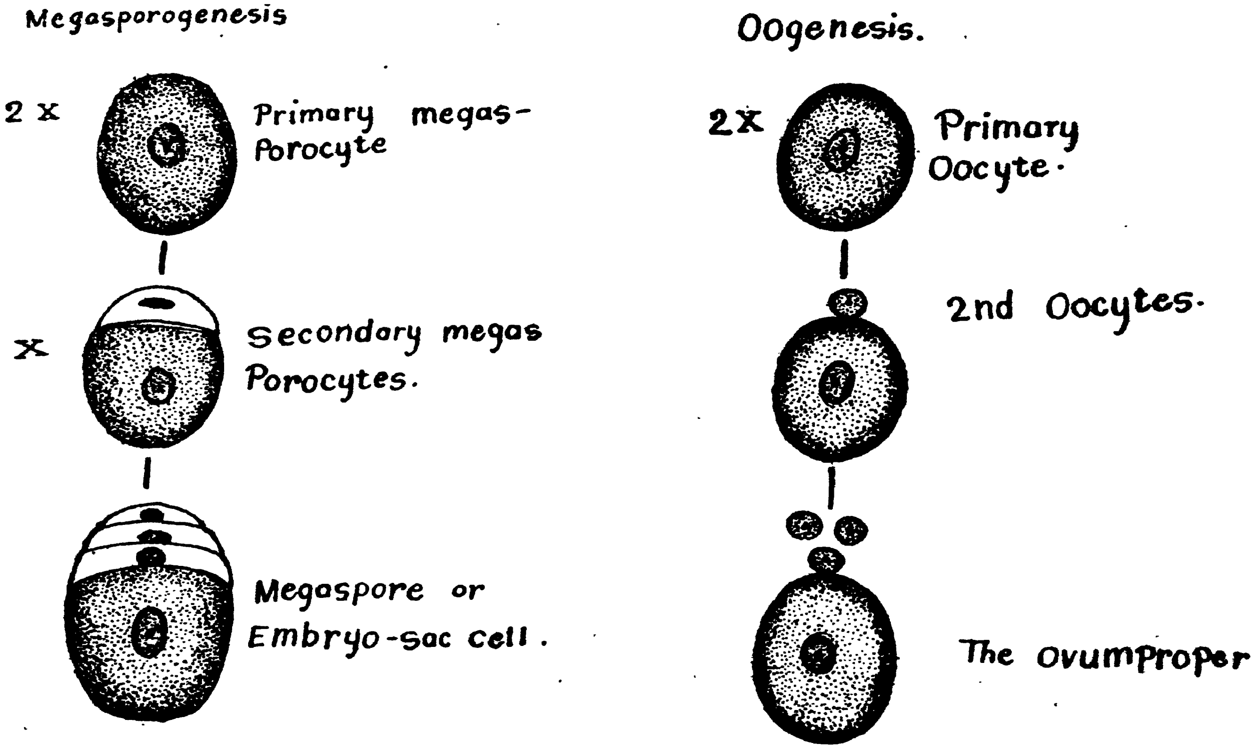
Here also the primary megasporocyte and Oocyte are diploid and the reproductive cells produced are haploid. It will be seen that in both cases only one functional cell is retained. Thus the megaspores and the micropores in plants are similar to the gametes in animals in their origin and development and it is perhaps on this account that some Botanists have called them sexual cells.

But they differ in their further behaviour; the haploid cells in plants germinate and produce the gametophyte, whereas the haploid cells in animals cannot produce unless they are united with other cells which may be called their complements. "The process of haplosis is just the same in both cases, but the difference lies in the behaviour of the haploid cells produced."

It will not be out of place to give below a few lines from an article "on the meiotic phase in animals and plants" by J. B. Farmer, and J. F. Moore, appearing in the journal on microscopia.

"The actual point in the life history at which the meiotic phase may occur is not identical in every organism . . . ,

FIG. 2.



2 X = the numbur of chromosomes double
X = the number of chromosomes halved

"On the one hand in metazoa the divisions included in the meiotic phase invariably lead directly to the formation of the sexual cells. In plants on the other hand not only is the position of the phase far more variable, but it never culminates, so far as is known, directly in the production of sexual cells. The latter are only formed after a greater or less number of intervening (post meiotic) divisions have been passed." It has been suggested here that in plants the haploid cells produced after reduction division are not gametes but spores.

Edmund B. Wilson in " Cell in development and heredity" (1925) rightly observes :—

> " Reduction or meiosis takes place at a particular part of the life-history, known as the meiotic phase".

The known cases fall into three clearly marked groups or types, which may be characterised as (i) Gametic or Terminal, (ii) Zygotic or Initial and (iii) Sporic or Intermediate meiosis.

(1) Gametic and Terminal Meiosis is characteristic of animals generally.

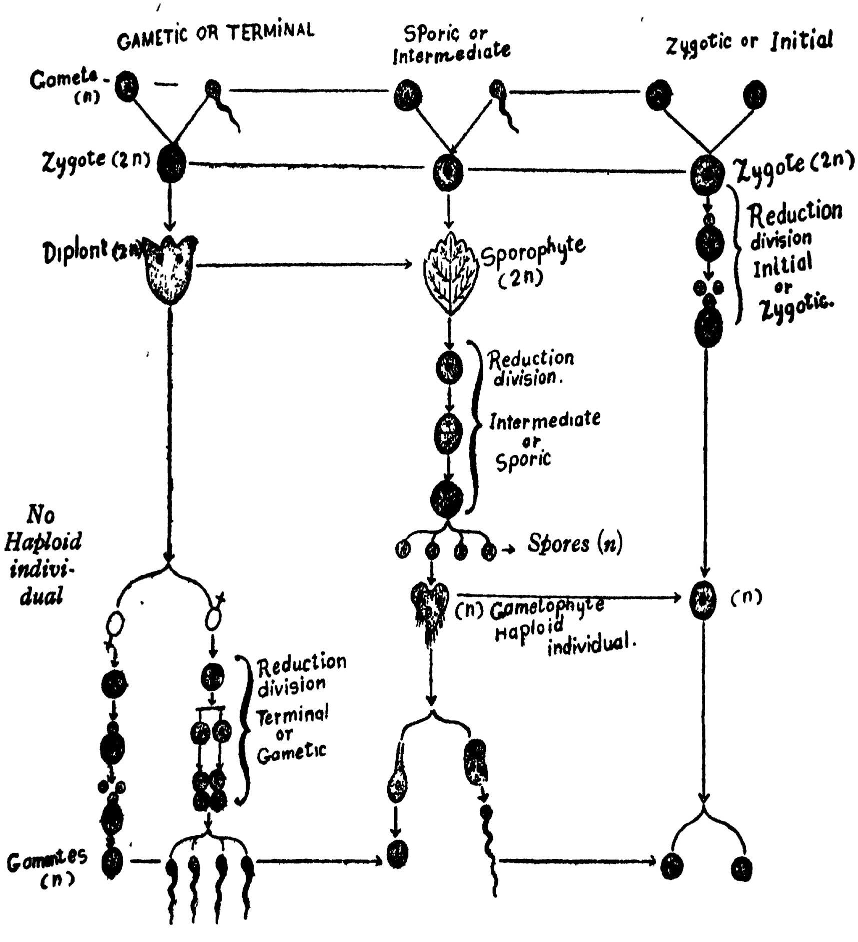
(2) Zygotic or Initial meiosis is a rare but interesting form which stands at the opposite extreme from the gametic type. At present it is found in a few Algæ and in certain sporozoa.

(3) Sporic or Intermediate meiosis is characteristic of all the higher plants and also occurs in some of the Thallophytes, but is thus far unknown in animals. The meiotic divisions here take place at some point in the diploid organism, intermediate between the Zygote and the formation of the gametes and their products are not gametes but asexual spores (tetraspores, embryo-sacs, Pollen Grains etc.). Here, therefore, the meiotic divisions form part of the general process of sporogenesis and involves an alternation of generations as follows :—The spores (being products of meiosis) receive the haploid number of chromosomes and develop without fertilization into a haploid gamete-producing sexual generation known as the haplont (in plants the gametophyte) which intervenes between meiosis and gamete formation. From this organism arise the gametes by ordinary mitosis ; and by their Union is produced the Zygote from which arises a diploid asexual spore-producing diplont (in plants the sporophyte) thus completing the life-cycle. The following diagram (Fig. 3 on p. 10) will be of great use in this respect.

It would be seen from the diagram that reduction division is terminal in the first column (animals) ; intermediate in the second column *i. e.* higher plants and initial in the third column *i. e.* in lower animals and plants.

The observations made by Dahlgren in 1915 on the sporogenesis of Plumbajella micrantha are of peculiar interest in this connection. The primary megasporocyte in this plant does not divide into secondary megasporocytes but at the close of the first meiotic mitosis, no

FIG. 3.



wall is formed between the two daughter nuclei which divide again giving rise to four nuclei lying free in the cytoplasm. These granddaughter nuclei do not undergo any further division but one of them directly becomes the nucleus of the Oosphere or female gamete, two of the remaining three, fuse to form the endosperm nucleus, while the fourth goes to the other end of the cell to degenerate. Sharp in

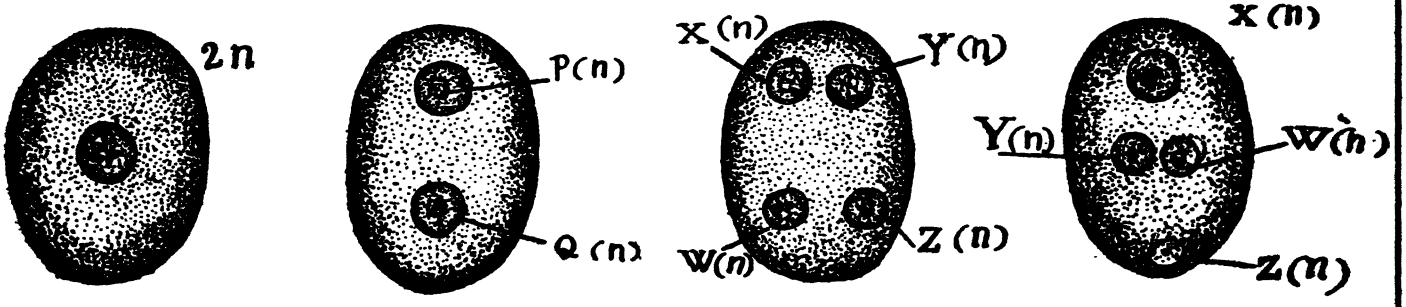
"Introduction to Cytology" observes: "This is the only known case among higher plants in which the gamete is the immediate product of meiosis, as in animals. No cases of a similar derivation of the male gamete are yet known." Similarly other Botanists have looked upon Plumbagella as a solitary instance of a plant behaving like an animal in the production of the female gamete.

I have my own doubts as regards this peculiar case of Plumbagella. Nature has been very steady and consistent in introducing changes as adaptations to certain physiological necessities. The gradual development of the asexual generation, with corresponding reduction of the gametophyte without in any way impairing the efficacy of the sexual cells, is the general course adopted by Her in the evolution of higher plants. The function of the male gametophyte is over with the production of the male gametes and therefore it does not matter much if it be a bit smaller and short-lived; but the female gametophyte, having to supply nutrition to the developing embryo, is bound to survive even after the production of the female gamete and is also much larger. Both the nutritive and reproductive activities of the prothallus are put to a more severe test here than in the male prothallus. Naturally, therefore, we find that reduction in the male gametophyte began, even earlier than in the female gametophyte. But this condition which exhibits itself in all plants higher than the Bryophyta, appears to be reversed in the solitary instance of Plumbajella, *viz.* the total absence of the female and presence of the male gametophyte.

The most important question in this connection is the order of succession of the reduction and the equation divisions in the meiotic mitosis. Weismann assumes that the first division is equational and the second reductional. Strasburger, Farmer and Moore and later writers on the other hand think that the first division is reductional, and the second equational. Wilson thinks that "pre-reduction probably constitutes the general rule," and in the vegetable kingdom at least, it appears to be most common. Now Plumbajella considered from this point of view clearly shows the presence of an extremely reduced gametophyte. The primary megasporocyte at the very first meiotic mitosis undergoes reduction division so that only two daughter nuclei are formed, (P and Q,) each containing N number of Chromosomes *i. e.* half of what were present in the Primary mega-sporocyte. (See Fig. 4 on p. 12.)

The daughter nucleus P divides into two grand-daughter nuclei X and Y, of which X becomes the Nucleus of the female gamete (Oosphere); in the same way Q divides into two grand-daughter nuclei W and Z out of which Z goes to the other end of the cell to degenerate while Y and W come to the centre and unite to form the endosperm nucleus,

FIG. 4.



Megasporogenesis in Plumbajella.

Here the daughter-nucleus P has got the morphological value of the nucleus of the embryo-sac cell and Q represents the nucleus of the degenerate mega-spore. While the grand-daughter nucleus X has got the morphological value of the nucleus of the female gamete and the nucleus Y possibly represents the nucleus of a prothallial cell. Just as the nucleus of a microspore (Pollen Grain) divides into the generative and vegetative nuclei, in the same way the nucleus P of the megaspore is divided into X and Y, X corresponding to the generative nucleus and Y to the vegetative nucleus. Here the generative nucleus instead of dividing and giving rise to two gametes is at once converted into the female gamete.

Thus the mega-gamete X is not the immediate product of reduction division, but one mitotic division intervenes between it and the latter. I, therefore, think that even in the case of Plumbajella there is an extremely rudimentary gametophyte being represented by two nuclei (X and Y) only.

We have so far seen that the haploid cells produced by diploid plants and animals differ a great deal in the functions they perform and have to be classed under different categories. In morphology structural similarities count a great deal in determining the nomenclature to be used; but in the present case, we are obliged to give more preference to functions than to structures, because the very basic idea in sex and sexuality is rather functional than structural.

In Ulothrix, Ectocrapus and allied forms the Zoospores germinate and give rise to new plants. But at times two Zoospores unite and the united cell divides and sub-divides and gives rise to a new plant. Here the first cell is known as an asexual cell, while the other two cells, which unite are known as sexual cells. All the Zoospores are alike but we call the first Zoospore as asexual and the last two as sexual because there is functional difference between the two. Again, if one of the two sexual cells comes to rest earlier while the other continues to move, the one that comes to rest is recognised as the female cell while the second is looked upon as the male. In this case also it is the difference in the functional activities of the two cells that determines maleness and femaleness. Thus functional differentiations are first to appear while structural ones appear later on, only to enable the organism to perform the work allotted to it in the best manner possible.

Now if the haploid cells produced by a diploid animal are sexual and on that account it is usual to recognise the individual as male or female; the haploid cells produced by a diploid plant are asexual and therefore neither the reproductive cells nor the individuals producing them can be called male or female and if we do so, we shall be using two terms contradictory in themselves which is absurd.

IV. The use of the terms will introduce ambiguity in scientific language especially in the Gymnospermia where the gametophyte can be better recognised than in the Angiospermia. The terms are already used in describing the staminate or pistillate plants and they will have to be used in the description of the gametophyte as well. Thus the staminate sporophyte and the male-gamete-producing gametophyte will both be called as the male plants; in the same way the pistillate sporophyte and the Oosphere-producing gametophyte will both be called the female plants. The terms being thus used in two different senses, a kind of hazy mist of ambiguity hovers about them, and it is very likely that one phase may be mistaken for another. To avoid this ambiguity the use of the terms in the description of sporophytes should be discontinued.

V. Their use has also led to slightly inaccurate statements in some branches of Botany. In plant breeding, for instance, the terms male and female are freely used to describe the staminate and pistillate plants and flowers. Attempts are also made to find out the conditions of sexuality in them. Santos' experiments on Elodia have proved that in the staminate plant there is an uneven pair of Chromosomes, the larger of which may be compared to the X Chromosome and the smaller one to the Y Chromosome. In Sporogenesis half the number of Pollen grains contain X while the other half contain Y. It has also been proved that in the tissue cells of the Pistillate plant there is the larger pair of chromosomes XX so that the egg contains X. From this phenomenon it has been concluded that "there seems little doubt that here is a sex chromosome mechanism exactly equivalent to that found in the animal kingdom. Two types of Pollen Grains X and Y produced in equal numbers and mating with one type of egg X, result in 50 p. c. female individuals XX and 50 p. c. male individuals XY."

To say that the Pollen Grain mates with the egg is not consistent with facts; for it is the male gametes that unite with the female gametes, and not Pollen Grains with eggs; they being asexual cells are not expected to unite.

But it may be assumed for the case of argument that by Pollen Grain is not meant the asexual cell proper, but the male gamete that is produced from the rudimentary sexual plant which the Pollen Grain gives rise to; and by egg is similarly meant the female gamete produced in the germination of the embryo sac cell. But even then it is inaccurate to say that by the union of these two gametes there are the male and female individuals produced. Generally in plants the union of two gametes leads to the production of the asexual plant and not the sexual one.

It is however to be noted in this case that since XY Chromosomes are found in male animals and the same pair is found associated with the staminate plant of Elodia it appears that these Chromosomes indicate the nature of the sexual plant that the Pollen Grains give rise to; and it is simply for the sake of convenience that the Elodia plant is called male by way of transferred epithet. For similar reasons the Pistillate plant of Elodia is called female. Wilson in his "Cell in development and Heredity" has expressed similar views on the point; he writes: "It is, however, important to bear in mind that in dioecious plants a sexual differentiation is clearly shown already in the diploid sporophyte, the sexual characters being as it were thrown back or impressed upon the asexual generation. In practice, therefore, it is found convenient to speak of staminate (microspore or pollen producing) sporophyte as male and of the pistillate or megaspore producing ones as female." (P. 812).

If we were to accept this as an explanation of the use of male and female, then these terms will have to be looked upon as being used to indicate the sex not of Elodia itself but of the sexual plants produced by the asexual spores thereof. And in that case there is the fallacy of the ambiguous middle or of four terms. The term sex-chromosome will then be used in one sense while speaking about animals and in quite another sense while speaking about the plant; in fact it is not used to denote identical individuals.

In the case of animals the sex-chromosome determines the sex of the individual in whose somatic cells it is found, while in the case of Elodia it is found in the somotic cells of the plant itself, but it determines the sex of the progeny of Elodia, not of Elodia itself.

Really speaking, from the two types of Pollen Grains there are produced two kinds of male plants 50% containing X and 50% containing Y. We are thus led to believe that Gametophytes with the X Chromosome are male and Gametophytes with Y Chromosomes are also male. But in the case of animals those that possess XY are male. And still we are asked to believe that "here is a sex chromosome mechanism exactly equivalent to that found in the animal kingdom". Again the embryo-sac cell has the X Chromosome and the gametophyte will also have the X Chromosome. Here we obtain a gametophyte which has the X Chromosome and is the female. But we have seen above that the gametophyte with the X chromosome is male. Thus the gametophyte with the X Chromosome may be male or female.

Can we really call the X and Y in the case of Elodia as sex-chromosomes? The sex chromosomes are always very definite in their connotation and denotation. In the present case there is no definiteness about the denotation. The sex-chromosome ought to be the only discriminating factor between the two sexes so that there should always be an only particular number of chromosomes to determine the sex. In the present case the X chromosome stands for the male as well as for the female sex, while the male sex can be represented by X or by Y. I really doubt whether this should be called the sex Chromosome mechanism.

We have thus seen that XX and XY which are recognised as sex-chromosomes are not present in the sexual individuals while those chromosomes that are present in the sexes do not represent definite sex.

We have looked so far at the whole problem from different points of view and at every step we have been confronted by some inaccuracy connected with it. Sphaerocarpus is another classical example in this connection. In this case also the male gametophyte has got the Y Chromosome while the female one has got the X Chromosome. The XX and XY chromosomes characteristic of animals are not found in sphaerocarpus as well. And I am sure that in plant life we shall not get a sex-chromosome mechanism exactly equivalent to that found in animals. Because in both the kingdoms the conditions of sexuality are different. If in the animal kingdom it is the diploid individual that is male or female, in plant life it is the haploid individual that possesses sex, the diploid one being the sex-less sporophyte. In the "Cell in Heredity and Development" Wilson rightly observes that "the problem of sex determination in higher plant assumes a somewhat different aspect from that offered by animals, since in the former the true sexual generation or gametophyte is haploid organism while the diploid generation is an asexual sporophyte. Obviously therefore the Chromosomal relations of the true males and females (*i. e.* the Gametophytes) cannot be identical with those of animals; we cannot for example suppose the female to be XX and the male XY, since these conditions can only occur in a diploid organism." (P. 812.)

VI. These inaccuracies and mistaken notions are imperceptibly creeping into our Indian Literature and are likely to instil wrong and mistaken ideas in many a young mind. Many of the Indian books, periodicals and journals have already copied out the mistakes that are found in English Books. Plants and flowers have been stamped as नर (male) or मादी (female); the stamens have been styled as पुरुष (males), the Pollen Grains (पराग) as the male cells and many other mistakes, of in no way less serious nature, have been committed. By way of illustration I shall give below a few of them from Marathi literature only.

The Century English Marathi Dictionary by Ranade tries to give Marathi equivalents to English Scientific terms; and in doing so, a very substantial service has been rendered to the Literature no doubt. But the Marathi Terms suggested have been simple translations of English Terms and as such have copied out the mistaken sense as well.

The terms Naramandala (नरमंडल) and Punkesaramandala (पुंकेसरमंडल) have been suggested for Andræcium; but the exact rendering of the 1st root in the term, viz.—Andros (=man) by Nara (नर) or even by Punkesar (पुंकेसर) introduces the wrong idea of maleness in our literature. Some other writers have suggested the terms Punkosha (पुंकोष) for andræcium, Strikohsa (स्त्रीकोष) for Gynæcium, Punkesara (पुंकेसर) for Stamens and Strikesara (स्त्रीकेसर) for Carpels. It will thus be seen that these mistaken terms have been introduced into our literature because the English terms have given them the mistaken ideas. When the most fundamental facts in the science of Botany have been thus misrepresented, there is every chance of many more mistakes of a similar nature being committed further on.

The idea that the stamens are the male individuals in a flower, has given rise to another mistaken idea that the Pollen Grain is the male cell; and in this manner series of mistakes have been committed. The mischief does not stop here. All these mistaken ideas in their train are being introduced, every day, into thousands of young minds.

Prof. R. V. Damale of Cawnpore has published a book on Botany in Marathi, known as Wanaspatiwichāra, (वनस्पती विचार). In this book many terms and ideas of mistaken nature have been given. On page 161 the anther has been described as really being a box of the male element.[1] On page 164 the Pollen Grains have been described as feeling their way to the Ovules through the style and the term that has been chosen for style is such as expresses its capacity to allow a passage to the Pollen Grain.[2] On page 169 the Ovule has been described as bearing a micropyle which allows the Pollen Grain to enter in.[3] On the same page two kinds of spores have been named, one is called the male spore and the other is the female spore; the male spore is in the Pollen Grain and the female spore is in the Ovule.[4] Mr. V. N. Gokhale has written a small book on " The Life of Plants " (Wanaspati Jiwan वनस्पती जीवन) in Marathi, in which he states that the Pollen Grains pass through the style to the Ovules and Unite with them.[1] Mr. J. M. Chakradeva, B.A., B.AG., B.SC., has written a book in Marathi as an Introduction to Botany called "Udbhijya Shāstra-Praveshikā" (उद्भिज्य शास्त्र प्रवेशिका). On page 56 of this Book the writer states that the Pollen grain enters the Ovary through the style and then its juice unites with the juice of the carpel. This is known as fertilization.[2] Many more instances of this type can be given from books intended for the younger generation. And this state of things will continue unless these inaccurate terms have been rendered into correct forms. I request my friends to consider these instances and many more of a similar nature, and ask them whether they still hold that we as men of learning understand these differences and that there is no need of effecting change in the nomenclature.

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[1] Parāgapitikā Mhanaje Purushatwapetārā āhe (परागपीटीका म्हणजे पुरुषत्व पेटारा आहे). Here the term परागपीटीका has been suggested for Anther.

[2] Parāgakana strikesarāgrāwara (Stigma) paduna parāga-wāhinituna rastā kādhita Bijāndākadesa jātāta. (परागकण स्त्रीकेसराग्रावर (stigma) पडुन परागवाहिनीतुन रस्ता काढीत बीजाण्डाकडेस जातात.) The term परागवाहिनी has been suggested for style.

[3] Bijānda-he wātole asuna tyāwara eka randhra asate, he randhra parāgakana āta shiranyāsa upayogi padate. (बीजाण्ड—हे वाटोळे असून त्यावर एक रंध्र असतें, हे रंध्र परागकण आंत शिरण्यास उपयोगी पडतें.)

[4] Paragakanāmadhye purushajananapeshi (male spore) tasecha Bijāndāmadhye strijananapeshi (female spore) asatāta. (पराग कणामध्यें पुरुष जननपेशी (male spore) तसेंच बीजाण्डामध्यें स्त्री जननपेशी (female spore) असतात.)

VII. It will not be so difficult to effect the change here in India, where the science has been introduced only recently. The European terminology has the back-ground of antiquity and it will be a bit more difficult to effect the change there. But the case is different with us in India. The science is still in its formation and therefore it is but proper that the change should be effected even now, with a view to avoid further mistakes.

But Science is more conservative and superstitious than religion, and so, many minds will not be prepared for the change. Green, Chamberlain and others have raised their weak voice against these terms with some effect no doubt, but a terminology consistent with facts has not yet been accepted by all in Europe and America. It is, therefore, feared that the change proposed will not be easily accepted even in India; as many of us appear to depend more upon personal authority than upon observations in Nature. From a private talk, that I had with many of my friends in Poona and Bombay, I have been led to believe that a line or two from Western Books is more effective in bringing conviction home to many of us than actual facts observed and conclusions drawn therefrom. Chamberlain, Green, Wilson, Sharp, Farmer and Moore are some of the authors whose views on this point are almost similar to those that have been expressed in this paper.

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[1] Fulātila parāga strikesarāwar jāuna padale Mhanaje nalikemadhuna Bijāndākade jāuna tyānchā Bijāndāshi Samyoga hoto. (फुलांतील पराग स्त्री-केसरावर जाऊन पडलें म्हणजे नलिकेमधुन बीजाण्डाकडे जाऊन त्याचीं बीजाण्डाशीं संयोग होतो.)

[2] Chudewar "parāgādhishthāna" jhālyānantara parāgawāhini vāte parāga warātakā madhye jāto āni tēthe tyāchyā āni kinjalkāchyā rasāchā ekajiwa hoto. Tyālā Dhāranā Mhanatāta. (चूडेवर "परागाधिष्ठान" झाल्यानंतर परागवाहिनीवाटे पराग वराटकामध्यें जातो आणि तेथें त्याच्या आणि किंजल्काच्या रसाचा एकजीव होतो. त्याला धारणा म्हणतात.)

Here the term वराटक has been suggested for the Ovary while the term किंजल्क, has been used for the carpel.

In the acquisition of our present Botanical knowledge we owe a good deal to the Western World in general and to Britain in particular. Different avenues in the field of Botany have been laid open for us and we are expected to work in those fields using our independent judgment wherever necessary. We should rather go to the logical conclusions of our argumentation as reason dictates and without trying to imitate the mistakes and inaccuracies that have crept into Botanical literature let us divest the substance of the deceptive garb in which it is clad. If the homologies established between the reproductive organs and cells of Pteridophyta and those of spermaphyte be correct, and there is no reason why they should be otherwise, the only conclusion that can be drawn is that which has been presented in this paper.

Summary.

We have so far tried to prove that the use of sex-denoting attributes in the description of the sporophyte of spermaphyta is unnatural and should, therefore, be discontinued.

I. That their use cannot be defended on the ground of antiquity.

II. That they cannot be retained by attributing conventional meaning to them. Because—

- (*a*) It is stretching the meaning a bit too far;
- (*b*) The conventional meaning and the usual meaning will be very often confounded; and
- (*c*) The conventional meaning will be soon forgotten and the terms will be understood in their usual meaning.

III. That there is no comparison between diploid animals and diploid plants. Diploid animals may be male or female but diploid plants cannot be; they are sexless. Because—

- (i) Haploid and diploid only show the 1 : 2 ratio between the sexual and asexual plants. The gametophyte may be haploid and sporophyte diploid but the converse of this is not true. We get haploid, diploid and tetraploid sexual plants in mosses (by special methods of regeneration) while a haploid sporophyte Fern is obtained from a haploid prothallus.
- (ii) Sporogenesis in plants is exactly similar to the gametogenesis in animals but if in animals the reduction division is gametic it is sporic in plants and only in a few Algae it is Zygotic.
- (iii) Even the solitary instance of Plumbajella is no exception, one mitosis intervenes between meiotic mitosis and the actual gamete formed.

(iv) It is function that determines the sex and not structure so that those reproductive cells that unite in order to reproduce are sexual cells, while those that reproduce by themselves are asexual *i. e.* spores.

IV. It (*i. e.* the use of sexual terms) will introduce ambiguity in the language, when sex-denoting terms are used for the sporophyte as well as for the Gametophyte.

V. Their use leads to inaccuracies in allied branches of Botany. An attempt to find out the sex-chromosome mechanism in plants similar to that found in animals is of this kind. In the treatment of the subject we come across many statements that appear to be inaccurate.

VI. The use of these terms in English has introduced similar wrong ideas and notions in the Vernacular and these wrong notions have contributed to further wrong statements.

VII. It is a bit easier to introduce the change here in India where the Science has been introduced anew.

A CONTRIBUTION TO PHOTOSYNTHESIS FROM THE BOMBAY UNIVERSITY

By

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The process of photosynthesis whereby the plant synthesises its own food as well as the food for all animal life, from carbon dioxide of the air and water from the soil with the energy derived from sunlight, has baffled some of the most brilliant minds for the last 150 years. Indomitable is, however, the spirit of science and attempts are being made to get a glimpse into the mystery of this process. It is now widely recognised that the very existence of animal and human life depends on this process occurring in plants and the right understanding and proper control may make for human progress and happiness. In our University this important problem is being tackled for the last seven years in the Botany Department of the Royal Institute of Science from various points of views and some useful and interesting results have been arrived at. It is therefore undertaken to give a brief account of the work done by Prof. R. H. Dastur and his students.

The process of photosynthesis like all other life processes is conditioned by a number of external and internal factors like light, temperature, carbon dioxide supply, chlorophyll and many others. The importance of the water content as an internal factor was not much realized and it was Dastur (7) who first pointed out its importance in the process.

Water content, a factor in photosynthesis.

In scientific research a simple observation often leads to valuable results and this has been found to be the case here. It was observed by Dastur (7) that in the mature leaves of Abutilon asiaticum, *G. Don.* starch was not formed uniformly all over their surface, as seen by Sach's iodine test but gradually disappeared from the marginal and apical regions of the leaves. As the leaves approached the stage of senescence, starch disappeared from the meshes of the vascular network and was found only in the cells bordering the veins. Finally the starch disappeared from the finer to the larger veins till its formation ceased completely. (Plate 1).

On microscopic examination of the starchless regions it was found that the chloroplasts had disintegrated and turned yellow. It is likely

FIG. 1.

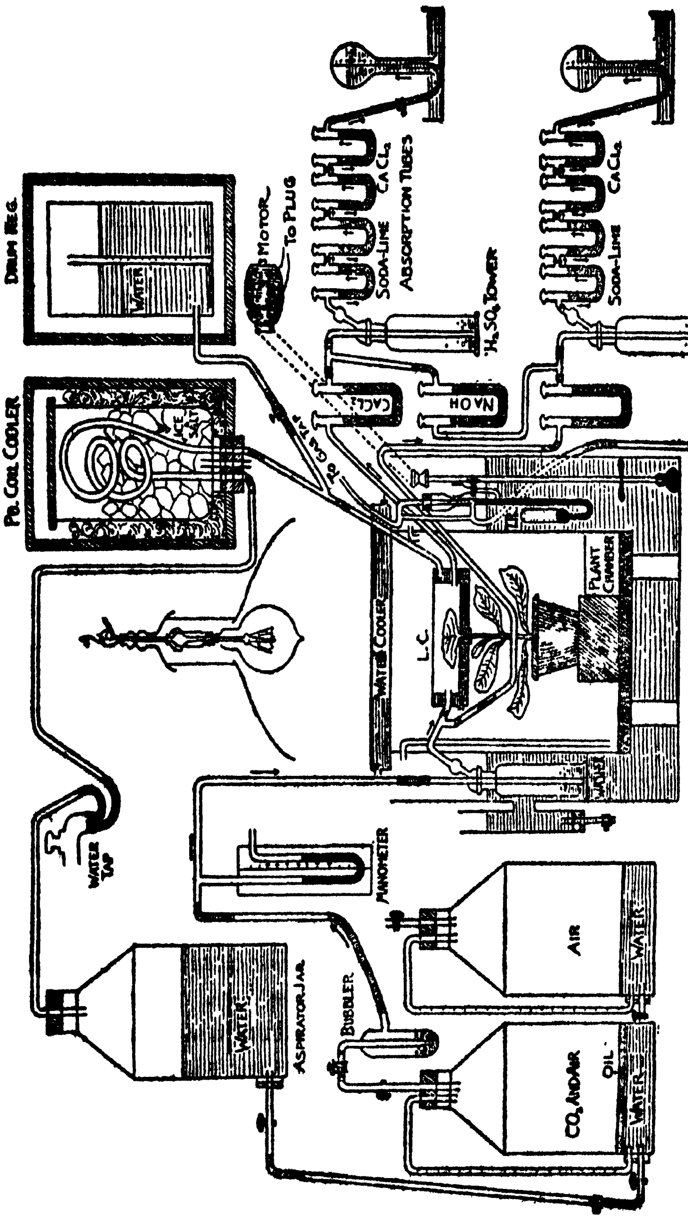


Diagram of the whole apparatus to measure photosynthesis in longitudinal section.

that the disintegration of the chloroplasts proceeded in the same characteristic manner as the disappearance of starch.

This mode of nonformation of starch, as Dastur (7) explained was caused by shortage of water supply as the photosynthetic cells at the margins, apex and in the meshes of the vascular network which are situated farthest from the conducting tracheides, were the first to show signs of photosynthetic decay, which gradually proceeded towards main veins. As a leaf matures, the increased demands for water necessitated mainly by transpiration, are not supplied from below and the cells situated the greatest distance away from the water conducting elements would be the first to suffer from the shortage of water and to suffer death.

Relation between Photosynthesis and water content.

The above observation led Dastur (8) to determine, experimentally the relations between the photosynthetic activity of a leaf and its water content. The rate of photosynthesis was determined by the continuous gas current method used by Kreusler (16,) Blackman and Matthæi (5), Willstatter and Stoll (32) and many others. Dastur (8) however made a new departure by working with a leaf *attached* to the plant as so far all the above mentioned investigators used in their experiments leaves *detached* from the plants and therefore not in their natural conditions. In the apparatus devised by Dastur (8) the leaf as well as the whole plant were kept under the same uniform conditions of experimentation as shown in Fig. 1. The results obtained by him indicate the close relationship between the rate of photosynthesis and the water content of a leaf (Fig 2.).

Chlorophyll from tropical plants and its quantitative estimation.

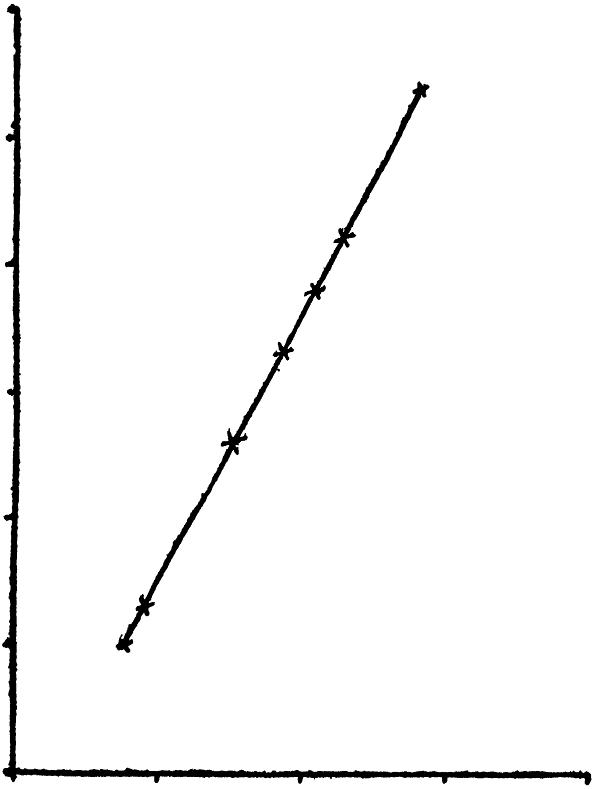
Chlorophyll as shown by Willstatter and Stoll (33) is an important factor in photosynthesis. In absence of chlorophyll the formation of carbohydrates does not occur in leaves. It was therefore necessary to determine the relative importance of chlorophyll content and water content of a leaf in its photosynthetic activity. Willstatter and Stoll (32) worked with a number of detached leaves in each experiment and this method as shown by Dastur (8) was open to objections. It was therefore necessary to investigate the relationships between the chlorophyll content and photosynthesis in leaves.

Willstatter and Stoll (33) used the colorimetric method for determining the chlorophyll content of leaves. This method was not found very suitable for determining minute quantities of chlorophyll that are generally present in a leaf. It therefore became necessary to devise another method by which the chlorophyll content of a single leaf could be determined with great accuracy.

Chlorophyll was so far not extracted from tropical plants in India and so Dastur and Buhariwalla (10) extracted and estimated chlorophyll from a number of plants growing in the Bombay Presidency and they have determined the conditions for extraction of chlorophyll in tropical climates.

The spectograph that was available for use was a quartz ultraviolet spectograph of Fuess and Co. (Steiglitz, Berlin), with a photographic attachment. The spectograph was permanently adjusted for the absorption in the ultra-violet, but a part of the visible portion of the spectrum upto the wave-lengths 4800 (Fraunhofer line F) comes within the range. Though the remaining part of the visible spectrum beyond 4800 is cut off, the spectograph serves the purpose well, as there is a sharp absorption band near the Fraunhofer line G at about 4300. (Plate 2.)

FIG. 2.



Curve illustrating the relation between photosynthesis and water content in the leaves of Spermannia africana *L.*

To determine the quantity of chlorophyll in a leaf, it is necessary to select a band which has selective absorption, and to determine the thickness of the layer of the chlorophyll solution upto which the same absorption band persists. The absorption spectrum of a solution is conditioned by two things, the thickness of the solution and its strength. When the length of the exposure and the width of the slit are kept the same, the thickness of the layer of the solution required will vary according to the strength of the solution: the greater the strength of the solution, the more persistent will be the same absorption band, and consequently the less thickness of the layer of the solution for the same band. To calculate the strength of the solution, three determinations are necessary: (1) to prepare a standard plate from a pure arc spectrum, with wave-lengths marked against the corresponding spectrum lines; (2) to determine the thickness of the layer upto which the selective absorption band of a solution of known concentration persists; (3) to determine similarly the thickness of the layer upto which the same band persists in a solution of unknown concentration.
Now if

C = strength of the known solution,
X = Thickness of the layer upto which the band persists in the case of the solution of the known concentration,
X′ = Thickness of the layer in which the band just persists in the case of the solution of unknown concentration, and
C′ = strength of the solution of unknown concentration,

$$C' = \frac{X \cdot C}{X'}$$

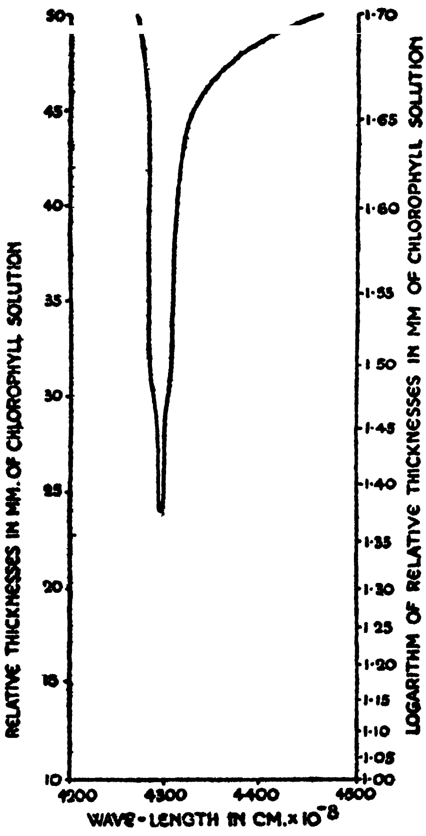
Since an iron arc is used as a source of light, a pure spectrum photograph is taken. The position of iron lines is obtained from the table of iron spectrum given in Watt's 'Index of Spectra'. Then the intermediate lines between two standard lines are marked according to the calculated values derived by interpolation formula as given in Baly's 'Spectroscopy'. The wave-lengths of these lines are then marked with a mapping-pen on the margin of the plate against their respective spectrum lines; thus a standard plate is prepared.

On another plate a pure arc photograph is first taken, and then a series of photographs with varying thickness of pure ether contained in a Baly's absorption tube having end-plates made of quartz. These ether spectrum photographs are then compared with iron spectrum on the standard plate, and it is found that there are no special absorption bands in the ether spectrum.

A standard solution of chlorophyll is prepared by dissolving 0·0411 grm. of solid chlorophyll, freshly prepared, in 5250 c.cs. of ether. The spectrum photographs of the chlorophyll solution of varying thicknesses are immediately taken as the chlorophyll tends to decompose. The chlorophyll spectrum is then directly compared with the standard plate, and it is found that there are the following absorption bands for 25 mm. thickness of the solution :

Band	1.	4494·6—4482·3
„	2.	4299·4—4294·2
„	3.	3370·2—3306·5
„	4.	3180·3—3083·8
„	5.	2844·0—2804·5

FIG. 3.



Graph of standard chlorophyll solution.

Of these bands the absorption band lying between the wave-lengths 4299·4–4294·2 (Plate 2) is used, and the determination of its apex reading taken in the following way. The wave-lengths of the left-hand and the right-hand lines of the absorbed part of the spectrum for different thicknesses of the standard chlorophyll solution are determined. These wave-lengths of the end lines of the right-hand and the left-hand ends are marked on the graph-paper against each respective thickness of the chlorophyll solution. Similar points are marked on the same paper, till the absorption band disappears, showing the lowest thickness of the layer of the solution. By joining the right-hand and the left-hand points on the two sides separately, the Hartley's curve is obtained with the apex. The apex reading of the thickness of the solution is marked, and is called the standard apex reading, being the apex of the standard solution. (Fig. 3).

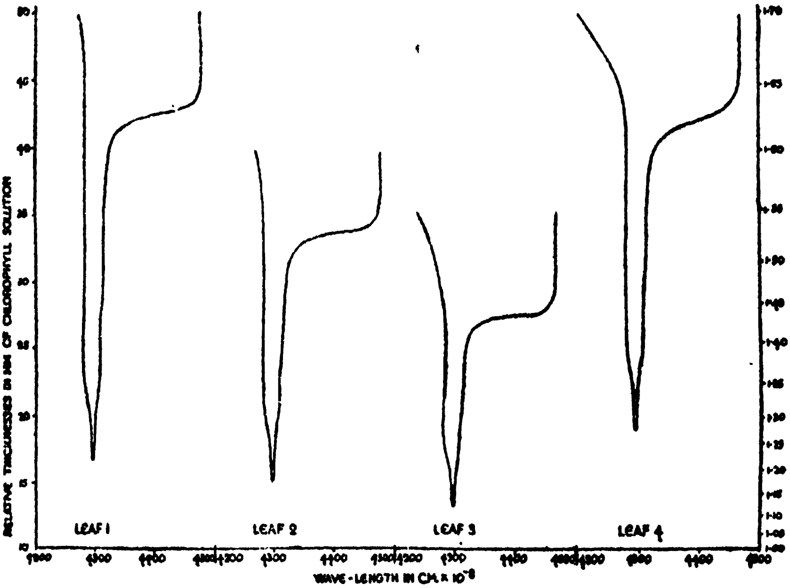
Similarly the photographs are taken of the chlorophyll solution prepared from a leaf whose chlorophyll content is to be determined. The curve is drawn for the same absorption band, and the apex reading of the thickness of the solution layer determined. According to the quantioe

$$C' = \frac{C \cdot X}{X'}$$

the concentration of the solution of the unknown strength is determined.

Fig. 4 shows the apex reading of the absorption curves of the chlorophyll solution prepared from four different leaves of Strobilanthus perfoliatus, T. Andres.

FIG. 4.



Graph of chlorophyll solutions from leaves of Strobilanthus perfoliatus.

The length of the exposure in all photographs taken in this investigation was 20 seconds. The slit is one division on the scale.

The chief source of error in this method is in the determination of the peak of the curve. The peak generally lies between two photographs, the one where the absorption band reappears, and the other one above it where the absorption still persists. So the thickness of the layer of the solution where the absorbed band exactly appears is situated between the two thicknesses at which the two consecutive photographs, are taken. Therefore the true thickness of the solution corresponding to the peak becomes difficult to determine. The difficulty is overcome in the following way.

The magnitude of the error introduced in determining the apex depends upon the difference of the two consecutive thicknesses of the solution between which the apex lies; the greater the difference, the greater would be the error. After determining the two thicknesses a series of photographs with the smallest possible differences in successive thicknesses is taken, and thereby the error is reduced to the minimum. This was the method employed in determining the standard apex reading.

The difference in the thickness between two photographs, where the apex actually lies, is 0·6 mm. The standard apex reading is taken as the mean of the two. So the error in the apex reading is 0·3 mm.

In determining the apex reading of the unknown solutions the same procedure is followed. In order to show that the error introduced on account of the difficulty in determining the peak of the apex is negligible, the results in the case of a leaf of Ricinus communis, calculated in the three ways are given below. The apex readings are taken at the two thicknesses, upper and lower, and the mean of the two. They are 19·39 mm., 18·83 mm., and 19·11 mm. respectively. The chlorophyll content, calculated according to the three readings, is 0·00349 grm., ·00360 grm., and 0·00355 grm. respectively. Therefore the error when the result is calculated according to the mean value is 0·00005.

An easy method of reducing the error without duplication of photographs is suggested below; if the maximum difference between the two thicknesses is 2 mm., it can be done by starting with a concentrated solution, and bringing down the apex reading below log 1·3. When the absorption band reappears, the intensity of the band seems to vary in different photographs of different solutions; in some cases the band is intense and in some cases it is faint. If the band is intense, the apex lies nearer the lower thickness. A series of photographs can be arranged according to the intensity of the band between the faintest and the darkest bands, and then it is easy to locate the apex of a solution by dividing the difference between the two thicknesses by the number of gradations of the intensity. In this case it is necessary to keep the intensity of the source of illumination and the length of the exposures the same in all determinations. By this method the apex reading, in the case of the leaf of Ricinus communis, was 19·21 mm., and the chlorophyll content calculated from this apex reading is 0·00352 grm.

Relation between water content, chlorophyll content and photosynthesis.

With the help of the above method Dastur and Desai (11)studied the relations between the water content, chlorophyll content and the photosynthetic activity of the leaves of some tropical plants at different temperatures, in order to determine the relative importance of water content and chlorophyll content on the photosynthetic activity of leaves and they expressed their results as Assimilation Number W and Assimilation Number CH, where

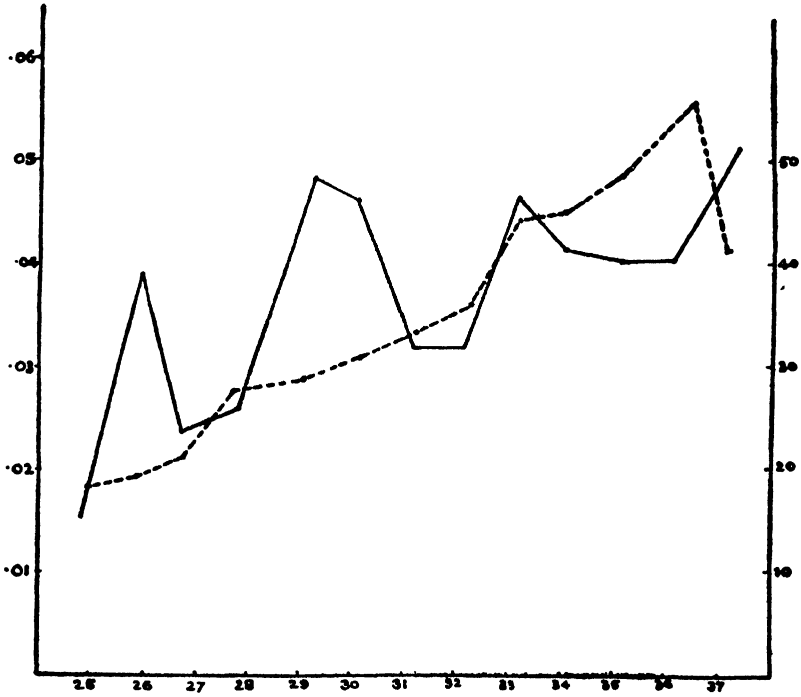
$$\text{Assimilation Number W} = \frac{\text{CO}_2 \text{ absorbed per one hour by 1 sq. dm. of leaf area}}{\text{Water content of 1 sq. dm. of leaf area.}}$$

$$\text{Assimilation Number CH} = \frac{\text{CO}_2 \text{ absorbed per one hour by 1 sq. dm. of leaf area}}{\text{Chlorophyll content of 1 sq. dm. of leaf area}}$$

according to the method adopted by Willstatter and Stoll (32) in expressing their results. If photosynthesis depended upon water content, Assimilation Number W should remain constant at the same temperature while it should rise with a rise of temperature. The same will be the case if the rate of photosynthesis depended upon the chlorophyll content.

In figure 5 the Assimilation Numbers W and CH are plotted against corresponding temperatures and they clearly show the greater influence of water content on the photosynthetic activity than chlorophyll content. They also found that the Assimilation Number W remained constant for the leaves of a species at the same temperature. The results show that the photosynthetic activity of leaves is controlled more by the water content than chlorophyll content,

FIG. 5.



Curves showing the Assimilation Numbers W and Assimilation Numbers CH of the leaves of Ricinus communis, *L*, at different temperatures.

Formation of Carbohydrates in leaves in lights from different sources.

The investigation was also the result of a simple observation made by Dastur that when plants were exposed to an electric lamp, starch did not appear, even after four hours' exposure, in leaves, made previously devoid of starch, while starch appeared within twenty minutes in leaves exposed to diffused sunlight. Dastur and Samant (12) undertook to determine quantitatively the different carbohydrates formed in leaves exposed to light from an electric lamp and diffused sunlight of equal intensities. But before they could do this they had to devise a special method for determining minute quantities of carbohydrates present in a few grams of leaves which are available for analysis as not more than six potted plants could be exposed uniformly to light from a 1500 Watt ½ Watt electric lamp. All the existing methods were found by them to be unsuitable for the purpose. They successfully modified the original method of Folin and Wu (14) to suit the requirements of their investigation and the whole method is being published by Dastur and Samant (13) for the benefit of other workers in plant physiology or plant chemistry. By this method the presence of one part of reducing sugars in 100,000 parts of water can be readily estimated.

They found, as a result of several experiments, that (1) the quantity of starch formed in leaves in artificial light is about one third of the quantity formed in leaves exposed to diffused sunlight. (2) The amount of cane sugar formed in leaves exposed to two lights is nearly equal and (3) the total carbohydrates formed in leaves under artificial light is nearly one half of the quantity formed in leaves exposed to Natural light.

In order to show that the decreased formation of carbohydrates in leaves in artificial light is not due to the depressed rate of starch formation, they experimented with the leaves of Allium Cepa, *L.* in which starch is not formed at all under natural conditions and they found that the total sugars formed in leaves exposed to artificial light was one-third the amount formed in leaves exposed to Natural light of the same intensity.

In order to account for these remarkable differences, not noticed before, in the photosynthetic activity of the leaves, in two lights of equal intensities, Dastur and Samant (12) measured the intensities of different rays of light from the two sources by means of a micro-thermopile and by photographic plates using Wratten "A" filter manufactured by Kodak Company. They found that light from the electric lamp has greater intensity of red rays and lesser intensity in the blue region than the intensities of the respective rays in natural light. The intensities of all the different rays of sunlight are nearly equal while that is not the case with the electric lamp.

The results obtained by Dastur and Samant (12) are of great importance as so far as it was not realised that all the rays of daylight are necessary for the photosynthetic activity of plants. Previous workers like Kniep and Minder (15), Timiriazeff (28, 29), Ursprung (30, 31), Lubimenko (17) and others have stressed the great importance of red rays in photosynthesis but they either did not use the different rays of light of equal intensities or their methods of measuring photosynthesis were not accurate. Briggs (6) has recently compared the photosynthetic efficiency of white light with that of isolated spectral regions and he found that the photosynthetic efficiency of the white light and that of the red and blue regions were the same. His method of equalising the total intensities of the different lights are definitely wrong and so need not be discussed here. Recent work of Popp (25) on the effect of different spectral regions on the growth of plants has an indirect bearing on the subject. He found that the blue part of the spectrum was quite necessary for the normal growth of plants and that full and vigorous growth was obtained in plants exposed to the full spectrum of sunlight, as compared to the growth made by plants in the light from which different regions of the spectrum were excluded. They also found that the carbohydrate contents of the plants grown in absence of blue violet region of the spectrum was much less than the carbohydrate contents of plants grown in the full spectrum. The findings of Popp (25) can now be adequately explained on the bases of the results obtained by Dastur and Samant (12).

This investigation is at present being followed up by R. J. Mehta in the Royal Institute of Science.

Photosynthesis under plane polarised light.

In recent years the study of the effect of the polarised radiation on Chemical reactions and Biological processes has engaged the attention of several investigators all over the world. Polarised light has been claimed to accelerate the speed of chemical reactions like the hydrolysis of starch by diastase [Baly and Semmens (1) and Semmens (26)] and of amalgams of alakli metals [Bhatnagar and his colleagues (2,3)] to affect the pharmacological properties of several drugs [Macht and his colleagues (19,20,22,23)] and to stimulate the growth of bacteria [Macht and Hill (21)] and [Bhatnagar and Lal (4)] and the growth of seedlings of wheat, Lupine, and Sunflower [Macht (18)]. Some have corelated the sexual periodicity of various marine organisms with the phases of the moon and therefore with the polarised radiations. Miss Semmens (27) claims that polarised light hydrolyses the leaf starch during the late hours of the afternoon when the light from the northern sky, is highly polarised. She also exposed plants to the light of the northern sky screening them from other extraneous light and found that the plants ultimately died as the photosynthetic activity could not proceed uninterruptedly in them.

It has also been suggested that the polarisation of light may be one of the correct asymmetric factors in nature responsible for the first production of the optically active substances on the surface of earth.

Another set of investigators could not duplicate the results already detailed above. For example Navex, Albert and Rupenstein (24) working with the highly controlled conditions found that starch hydrolysis was equally well accelerated by ordinary light.

If Miss Semmen's observations could be duplicated by more carefully performed experiments, they would have a profound bearing on the fundamental problem of photosynthesis. With this view, Dastur and Asana (9) investigated the effect of plane polarised light on the formation of carbohydrates in leaves under carefully controlled conditions.

They worked with both electric light and sunlight. A highly polarised beam of sufficient size and intensity was obtained in the former case by reflecting the light of a flood light lamp from a pile of about 20 glass plates, at the angle of maximum polarisation *viz.* 57. For simultaneous work with nonpolarised light, an ordinary 1500 Watt ½ Watt 230 volt Phillips bulb was used. As different light sources were used, their intensities were equalised and also the intensities of the different spectral regions studied.

To obtain polarised sunlight the following method was developed.

The sun changes its position from hour to hour and it is not possible to obtain a steady beam of light at a particular spot without a heliostat. The use of a heliostat was, however, out of question as the beam it gives is quite insufficient to illuminate even one single plant.

It is possible, however, to work with sunlight, about noon, when the sun moves through a very narrow arc of a circle, and in practically a horizontal plane. The sun shifts its position in one hour through 15^0. If the pile of glass plates is, therefore, fixed at an angle of 33^0 with the meridian point, the sun's rays from that point would make an angle of 57^0 with the normal to the plates and consequently the transmitted beam of light would be highly polarised. An hour before and another after the sun crosses this point, the rays would strike this pile at the incident angle of 42^0. For these two hours one could obtain a reasonable high percentage of polarised light and all the experiments were carried out during this period. The necessary details as regards the inclination of the sun during the different seasons, the standard time when the sum crosses the meridian etc., were kindly furnished by the Director of the Colaba Observatory. Experiments in ordinary sunlight of equal intensity were done under another beam of light transmitted from a pile of plates kept at right angles to the path of the sun's rays. The percentage of polarisation in the two kinds of light was determined by means of a Babinet's Compensator and about 80 % of light was found to be polarised as against 10 % in the ordinary light.

Results obtained showed that photosynthesis proceeded quite normally in polarised light. The amount of total carbohydrates under polarised light was in some experiments higher and in others lower than that obtained in non-polarised light. In order to see if polarised light had any stimulating effect or not the results were statistically analysed by the method of "t", adopted by Fisher for small samples. It was found that the differences were insignificant in all cases.

The effect of elliptically polarised light on photosynthesis is at present studied by L. K. Gunjikar in the Royal Institute of Science with a special apparatus devised for the purpose.

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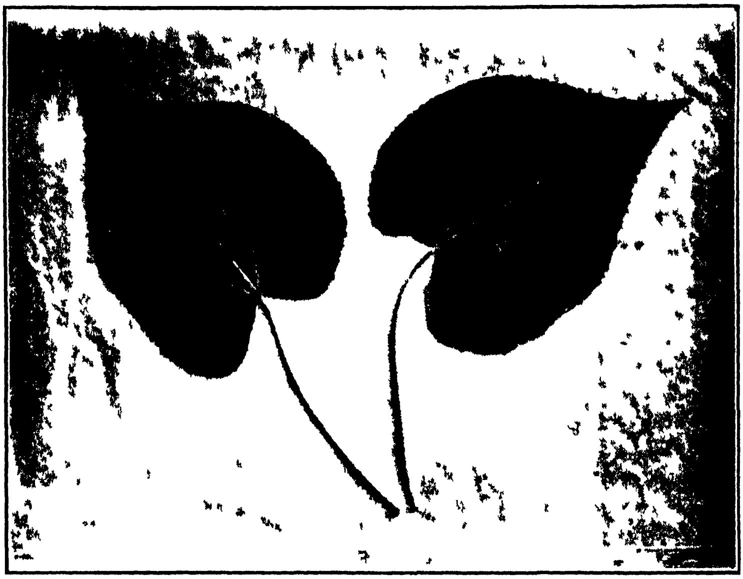
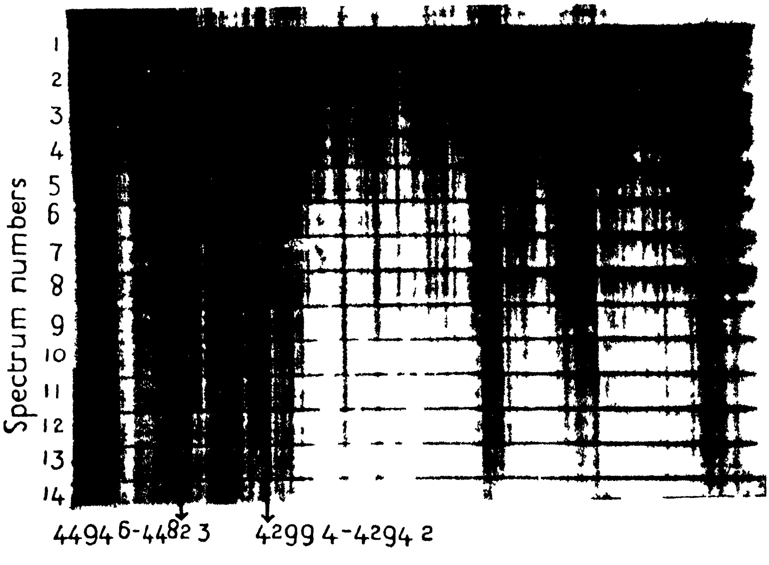
PLATE 1.



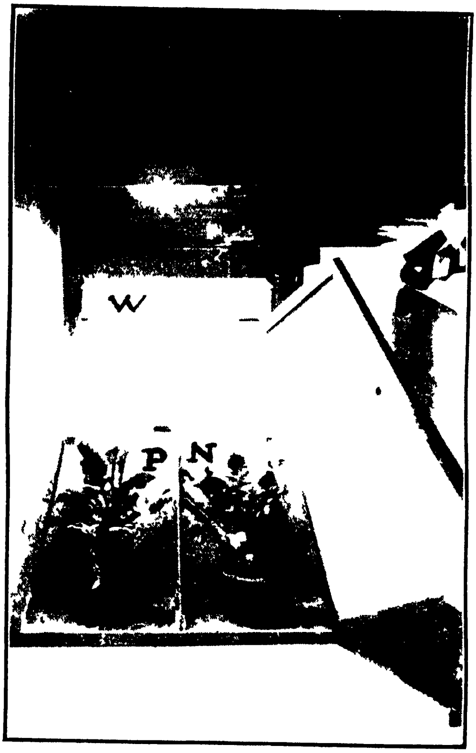
A photograph of the leaves of Abutilon asiaticum, *G. Don* showing the marginal and intravascular decay. The leaves were extracted with alcohol and treated with iodine. The unstained regions indicate absence of starch

PLATE 2



Absorption spectra of chlorophyll (a & b) solution in ether, showing absorption bands

PLATE 3.



Photograph of the apparatus to study the effect of transmitted plane polarised and non polarised light on photosynthesis

PLATE 4

Photograph of an apparatus to study the effect of reflected plane polarised light on photosynthesis (screens are removed)

PLATE 5

Photograph of an apparatus to study the effect of transmitted plane polarised sun light on photosynthesis.

PLATE 6

Photograph of an apparatus to study the effect of ordinary sun light on photosynthesis

In Plates 3 6 W = Water cooler N = Non polarised light, P = Polarised light, L — flood light lamp, I = Pile of glass plates at the angle of maximum polarisation

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CAULERPACEAE FROM MALVAN HARBOUR

By

S. C. DIXIT

Caulerpaceae is a family of the Siphonales. It is characterised by the simplicity of structure and the variety and the attractiveness of its forms. It is mainly tropical. It is usually found in the Littoral zone on rocks as well as soft sand and mud. It propagates vegetatively year after year.

Malvan is a beautiful small harbour on the western coast of South India. The Indian ocean there is open and the shore is mostly sandy. It is a favourable locality for algel growth. Assiduous search may reveal many interesting species and forms.

There are about sixty species of Caulerpaceae known. Twenty-one species are recorded from India and Ceylon of which twenty are from Ceylon, described by Svedelius (1) in 1906. The remaining one is mentioned by Dr. Borgesen (2) along with six known species which he collected from four different places in the Bombay Presidency. The writer has so far been able to collect seven species from Malvan. *C. fastigiata* found at Bandra (Bombay) by Borgesen has not yet been noticed at Malvan. The present list includes *C. verticillata* and forms of other species collected from Malvan in March 1928.

1. *Caulerpa verticillata* J. G. Agardh.

   f. typica. ramuli verticillate and in whorls often one above the other. (Plate 1) Found on small rocks covered by silt in shallow water near the fort.

2. *Caulerpa scalpelliformis* (R. Brown) Weber V. Bosse.

   A large plant growing on both sand and stone. Assimilators→15 cm. in length and 1 cm. in breadth with proliferous shoots. (Plate 2)

3. *Caulerpa crassifolia* (Ag) J. Ag.

   f. mexicana and *f. pectinata.* (Plate 3)

4. *Caulerpa taxifolia* (Vahl) *Ag.*

   It grew with other species of algae on mud. (Plate 4)

5. *Caulerpa peltata* Lamourx. (Plate 7)

   Discs 1·5 cm. margin entire; assimilators →15 cm. long.

6. *Caulerpa racemosa* (Foerskal) J. Agardh. (Plate 5)

   Var. clavifera. grew on rocks.
   Var. macrophysa. (Kuetzing) n. comb.
   Var. uvifera. grew on sands. (Plate 8)

7. ***Caulerpa sertularoides*** (Gmelin) Howe.

f. ***Brevipes*** (J. Agardh) Svedelius.

f. ***longiseta*** (J. G. Agardh) Weber V. Bosse. (Plate 6)

The first form grew on rocks while the second on sands. ***f. longiseta*** is tufted in habit; assimilators→12 cm. long. ***Halophila ovalis*** Hook grew along with it.

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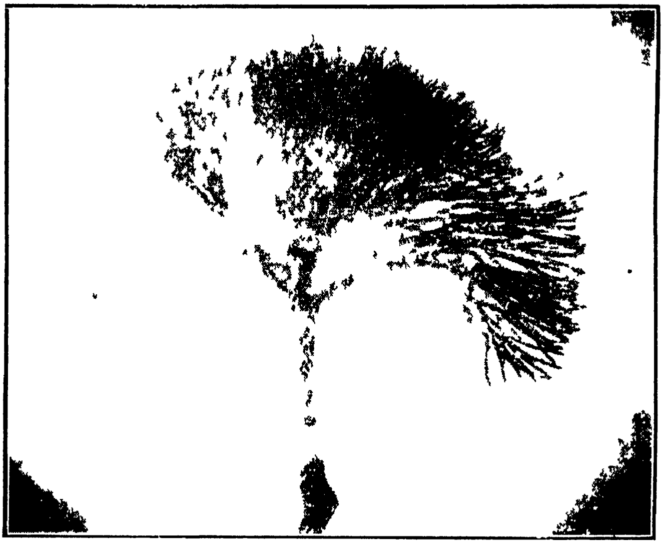
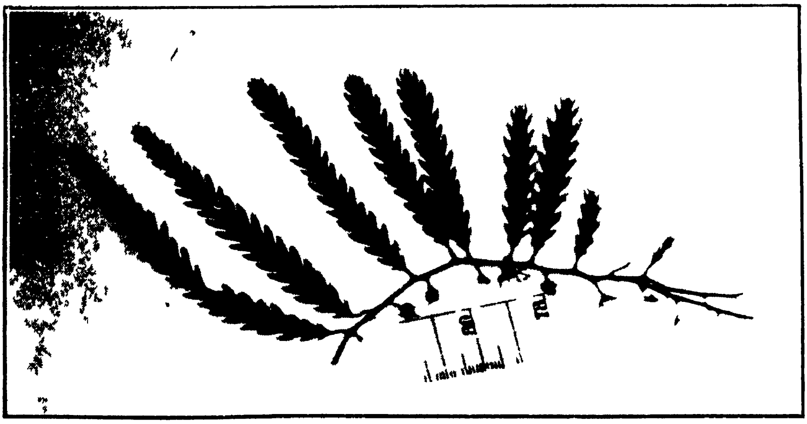
PLATE 1.



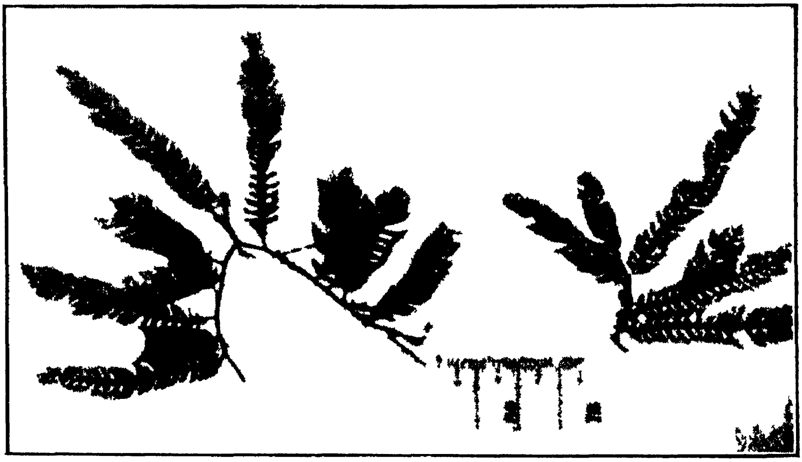
1. C. *verticillata* J. G. Agardh × 15

PLATE 2.



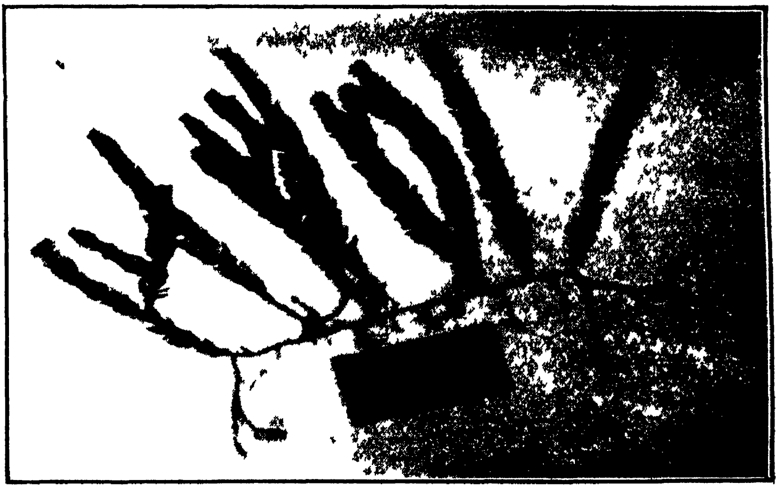
2. C. *scalpelliformis* Weber V. Bosse

PLATE 3



3 *C crassifolia f mexicana* J. Ag

PLATE 4

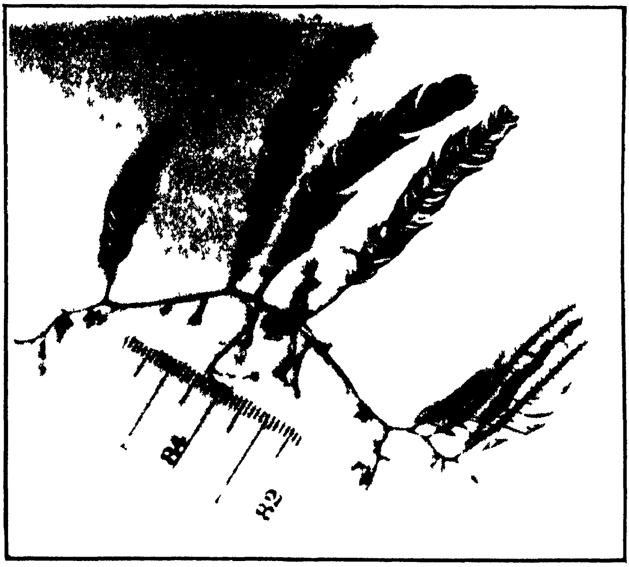


4 *C taxifolia* Ag

PLATE 5

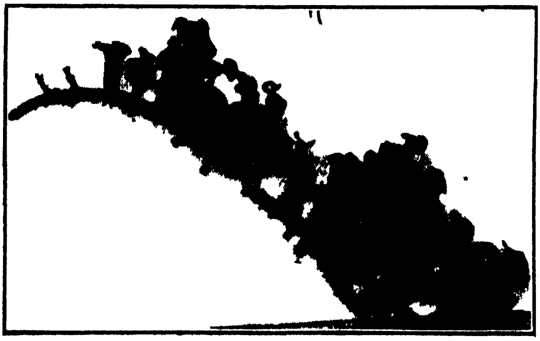
C. racemosa var. macrophysa

PLATE 6



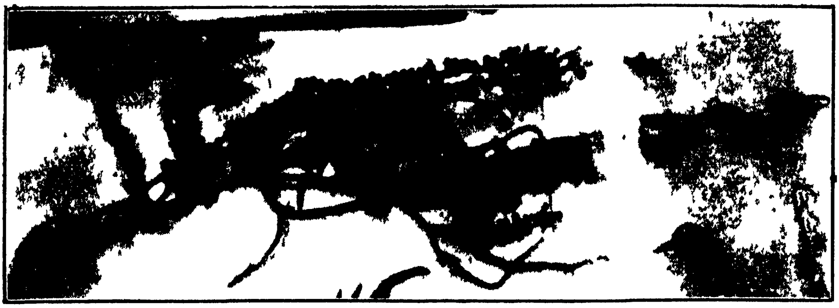
6. *C. sertularioides f. longiseta* Weber V. Bosse.

PLATE 7



7 C *peltata* Lamourx $\frac{1}{5}$ Nat size.

PLATE 8



8 C *racemosa var. uvifera* Weber 2/5 Nat size.

ON THE PHASICAL HISTORY OF THE THYMUS GLAND IN PLAICE OF VARIOUS AGES WITH NOTE ON THE INVOLUTION OF THE ORGAN, INCLUDING ALSO NOTES ON THE OTHER DUCTLESS GLANDS IN THIS SPECIES

By

S. H. LELE, M.A., M. Sc., Ph. D.

The Royal Institute of Science, Bombay.

(*with 4 text-figures and 3 plates*).

CONTENTS—Introduction—Material and Technique—Topographical Anatomy of the Thymus—Microscopical Structure of the Thymus—The Thymus in Specimens of Various Ages—Involution of the Thymus—Development of the Head-kidney—Note on the Thyroid—Note on the Supra-renal Bodies—Note on the Pituitary Body—Discussion and Conclusions—Acknowledgments—Summary—Literature cited.

Introduction.

This paper on the Phasical History of the Thymus Gland in Plaice of Various Ages with Note on the Involution of the Organ, including also Notes on the Other Ductless Glands in this Species is the first of the series of my papers on Some Aspects of the Thymus Gland of Fishes. This problem was given to me by the late Dr. J. Johnstone, Professor of Oceanography in the University of Liverpool, and the work of this paper was carried out under his guidance in the Oceanography Laboratory at Liverpool.

Material and Technique.

Most of the material required for this investigation was found in the Oceanography Museum of the Liverpool University. Additional fresh material was obtained at the Marine Biological Stations at Port Erin and Plymouth. The former material, preserved in five per cent. formalin, gave me good results when its sections were stained with Mayer's Glychaemalum and Eosin or with Mallory's Connective Tissue Stain. The fresh material used for the study of its histology was fixed in Bouin's picro-formol and Tellyesniczky's Acetic-Bichromate Mixture and treated with the former stains among others. Sections of four to six microns in thickness were found satisfactory for detailed study.

The ages of the various specimens were determined from the rings on the otoliths and the readings were kindly confirmed for me by Mr. R. A. Fleming of the Oceanography Department.

as the deeply staining small thymus cells are relatively few in the medulla these paler large ones appear to predominate there. They are known as the large thymus cells, or reticular cells.

The view regarding their origin has also changed and now they are taken as derived from the mesodermal cells which early penetrate into the increasing mass of deep-staining thymus cells derived from the branchial epithelium.

The reticular cells at the surface of the gland form a thin continuous layer against the surrounding connective tissue. Here and there in this layer are included capillary vessels containing red blood corpuscles. The cytoplasm of the cells of this layer is usually more deeply stained than that of the inside reticular cells. The cells of this layer send centripetal processes into the gland which are continuous with those of the inside reticular cells.

The surrounding connective tissue forms a thin membrane which closely follows the outline of the gland. The connective tissue fibres in this membrane are arranged parallel to the surface of the gland. This membrane with some outer loose connective tissue penetrates the gland in the form of septa between the marginal lobules (Plate 1, fig. 1, A). Along these septa blood vessels enter the gland. Towards the centre of the gland the septa become reduced to strands enclosing capillary blood-vessels. So in a section many of them are cut transversely in the region of the medulla. The finer branches of these capillaries do not have the adventitia or the outermost coat of connective tissue fibres.

At places in the loose connective tissue surrounding the gland are seen many thymus cells which have evidently emigrated from the main mass.

At least from the time the plaice becomes one year old (Plate II, fig. 2) numerous rounded or irregular clear spaces are seen in the thymus. These spaces are as large as a mass of a few thymus cells and usually contain some granular detritus. Round them the neighbouring thymus cells arrange themselves in a single layer and the cavities appear as multicellular cysts. The varying contents of these spaces indicate that they are formed out of some degenerating thymus and reticular cells and the products of degeneration become gradually absorbed in the lymph. The surrounding thymus and reticular cells seem to arrest the necrobiosis by forming a wall round them.

Some of the thymus cells shrink and become reduced to dense rounded specks of chromatin. Such pycnotic cells are seen scattered irregularly both in the thymus and in the surrounding connective tissue. Occasionally a collection of brownish, or dark, granules is seen in the thymus. It may be formed by the disintegration of pycnotic cells.

A few spherical masses of a thick coagulum (Plate I, fig. 1 B) are seen along the border of the thymus. When one of them is carefully examined under the high power, it is seen to be made of small spherical masses of varying sizes (Plate II, fig. 3 B). It also includes some nuclei of the thymus and reticular cells. They are seen in varying stages of degeneration. Some of the thymus cells may be partly embedded in the ball of coagulum. By the side of such balls may be seen a reticular cell with a few spherules of coagulum and two or three thymus cells included in its cytoplasm (Plate II, fig. 3 C). The processes of such a cell body shorten and it tends to become spherical. Thus it seems that some of the reticular cells are phagocytic on the thymus cells and produce this coagulum. As the process advances they also succumb to it. When this takes place in a few adjoining reticular cells with the thymus cells included in their meshes, all these unite and produce a relatively larger syncytium with nuclei in various stages of degeneration (Text-fig. 4).

The coagulum remains unstained in Hæmatoxylin-Eosin staining. It becomes bluish in Mallory's Connective Tissue stain. The spherical mass may also contain a few unstained brownish or dark granules. Occasionally a red blood corpuscle is seen disintegrating inside this coagulum.

Scattered among the thymus cells are to be found a few globules of mucus. Some of them are small and enclosed by single reticular cells, and others, relatively large are bounded by many such cells. (Plate III, fig. 3,5). The mucus is stained pale blue with Mallory's connective tissue stain and appears frothy. Thus it is easily distinguished from a coagulum ball. These multi-cellular mucus glands somewhat resemble the corpuscles of Hassal which are not usually present in the thymus of fishes.

The Thymus in Specimens of various ages.

An easily distinguishable thymus is seen in a larva of the plaice of 8 mm. in total length, and of 1·6 mm. in height. The larva reaches this size in about four weeks after hatching. In Text-fig. 2 are shown such of its structures as are seen in a whole mount. It also includes the outlines of the thymus and the pronephros reconstructed from transverse sections of another specimen of the same length. The thymus in this stage is about one-twentyfifth of a millimeter in length. It is oval in outline with its narrow end pointing posteriorly. It is situated immediately behind the last gill arch. It is thick in the middle and thus resembles a biconvex lens. In section (Text–fig. 3) it is easily made out on account of its small deeply stained cells. A transverse section of the larva showing the thymus often passes through the vagus ganglion which is situated as the deeply staining small thymus cells are relatively few in the medulla these paler large ones appear to predominate there. They are known as the large thymus cells, or reticular cells.

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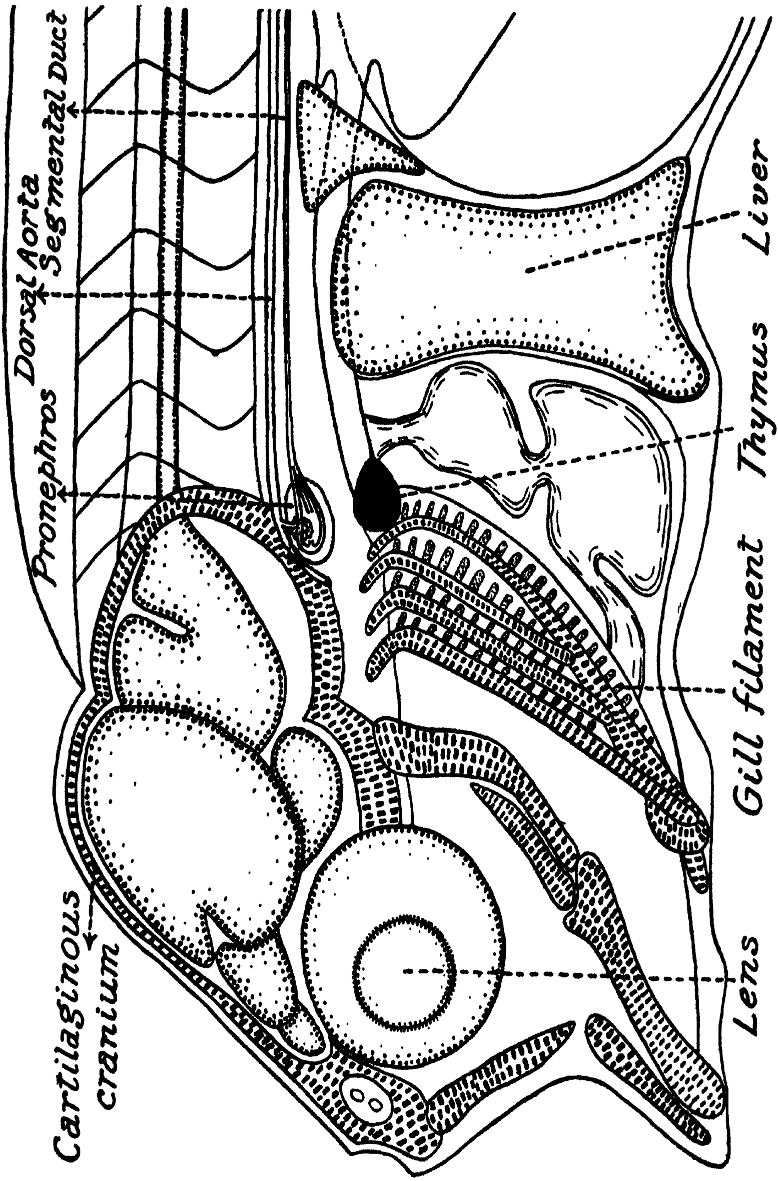
TEXT-FIG. 2.



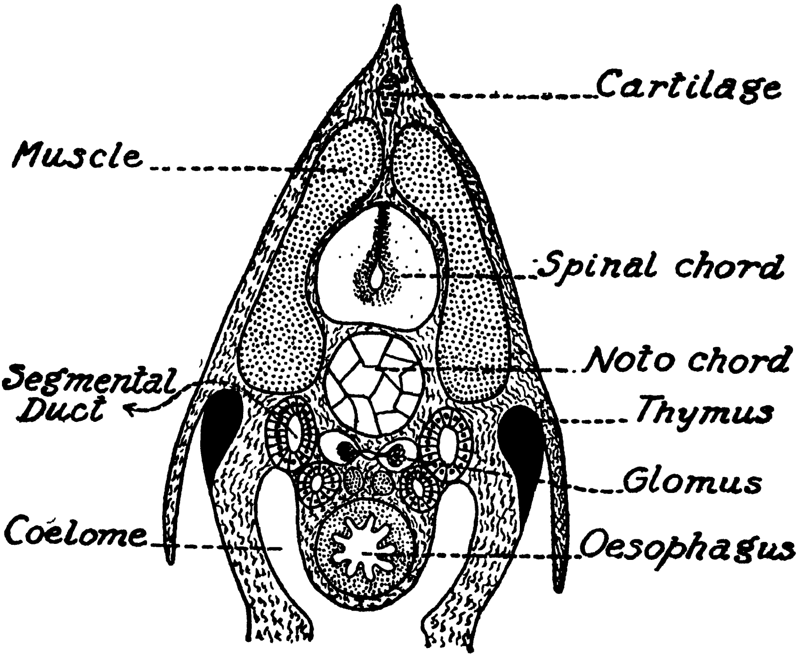
Lateral View of a 8 mms. Larva of Plaice showing also the Thymus and Pronephros reconstructed from sections.

is only two cells thick. It includes some mucus cells which are smaller than the mucus cells in its vicinity. On its inner side it is bounded by some loose connective tissue.

In a larva of 7·5 mm. in length the thymus is quite rudimentary. The rudiment is seen on three sections of 6 microns in thickness, and in each it consists of a few small cells stained deeper than the rest. This group of cells rests on a thickened epithelium at the junction of the ectoderm and branchial endoderm.

In a larva of 6·5 mm. in length even the thickened epithelium was hardly visible. This larva was fixed on its 20th day after hatching.

TEXT-FIG. 3.



Transverse Section of a 11 mms. Larva of Plaice passing through the region of the Thymus and the Pronephros.

In a larva of 11 mm. in length the thymus becomes three-twentieths of a millimeter long, and proportionately broad and thick. Now it is in contact with the ectoderm only by the lower half of its outer surface. In a transverse section (Text-fig. 3) passing through its middle it appears club-shaped with the handle pointing downwards. The ectoderm in contact with it is as thin as before. The ectoderm cells can be easily distinguished from the thymus cells on account of their distinct cell-bodies. Immediately inside the ectodermal covering the thymus cells are relatively few and the interspaces are larger than those further inside. Thus the thymus of the plaice does not show the third zone which has been described by Hammar in the thymus of certain bony fishes. Along its surface in contact with the inside connective tissue the reticular cells form a thin superficial layer and the thymus acquires a definite outline. At its anterior end the border is not quite definite and some thymus cells are seen scattered in the adjoining connective tissue. Some pycnotic cells are seen here and there in the thymus but it does not contain any mucus glands.

In a young plaice or metamorphosed larva 15 mm. long, the thymus is one-fifth millimeter long and proportionately broad and thick. Now its surface in contact with ectoderm appears proportionately smaller than before. A few rounded clear spaces appear inside it. In its middle the medullary region begins to appear. A few mucus globules are seen enclosed in reticular cells. Its surface is still entire.

In a plaice 7·5 cm. long and about one year old the thymus is 1·35 mm. long. Its margin is now divided into lobules. A few coagulum balls have appeared in the medullary region. A large number of thymus cells are seen scattered in the adjoining connective tissue at its anterior end.

The following table gives the ratios of the length of the thymus to the total length of the fish at various stages of its life.

Length of the specimen	Length of the thymus	Ratio of the length of the thymus to the length of the fish	Age etc.
8 mm.	42 microns	5%	4 weeks.
11 mm.	156 ,,	1·4%	6 weeks.
15 mm.	192 ,,	1·3%	8 weeks.
7·5 cm.	1·35 mm.	1·8%	1 year.
15·5 cm.	6 mm.	3·8%	2 years.
30·5 cm.	9 mm.	3%	3 ,,
40 cm.	14 mm.	3·5%	5 ,,
46 cm.	14 mm.	3·0%	7 ,,
52 cm.	negligible	...	10 ,,
,,	,,	...	17 ,,

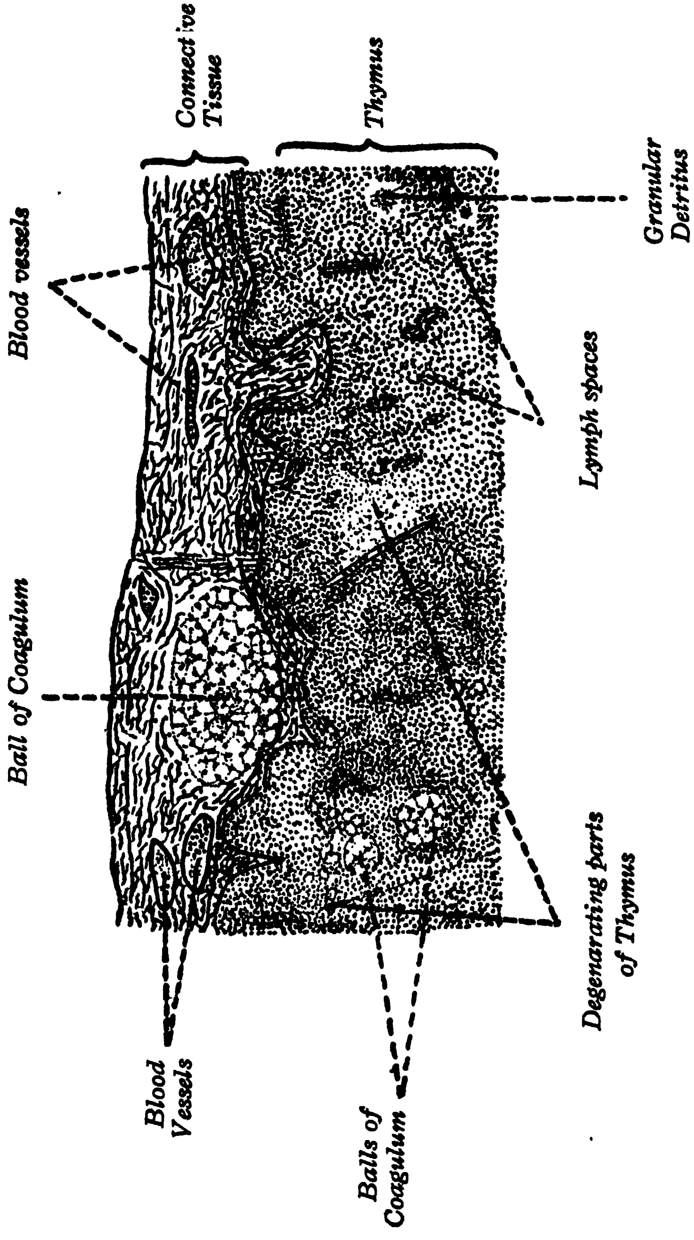
It is easily seen from the table that the thymus continues to grow faster than the body of the fish upto the time of its adolescence. Later its growth continues but it is less than that of the body.

All the lengths of the thymus given above refer to the thymus of the plaice on its ocular side. The thymus on the blind side was found as a rule to be a little smaller than that on the other side.

Involution of the thymus.

In the thymus of a plaice 46 cm. long and seven years old, the process of involution is seen going on actively (Text-fig. 4). The involution appears to be brought about chiefly by those agencies which had been working in the thymus since it began to differentiate into the cortex and the medulla. While the gland was growing vigorously the Necrobiosis was confined to a few isolated cells or groups of cells. Now it takes place on a large scale. At the same time the surrounding connective tissue becomes active and tries to cut off its blood supply. The thymus tissue is destroyed partly by its disintegration,

TEXT-FIG. 4.



Section of the involuting Thymus of Plaice seen under the low power of microscope.

and partly by its degeneration into a coagulum. Both the detritus and the coagulum are later absorbed in the lymph and are replaced by bundles of connective tissue fibres. This process works as shown below, The coagulum balls are now much larger and much more numerous than before. Those which are situated towards the margin or outside the margin of the thymus show only traces of nuclei. The process of the formation of coagulum is seen to be going on at places on as large an area as a single lobule. Some such large rounded masses are seen situated immediately outside the proper thymus. Some of them show to be secondarily subdivided by the encroaching fibres of surrounding connective tissue bundles.

The disintegration of the thymus and reticular cells seems to be now general and at places more active than elsewhere. Preliminary to this both the kinds of cells become hypertrophied. Some of the reticular cells (Plate III, fig. 3, 2) become relatively very large. The chromatin network of the thymus cells opens out and later breaks into granules. Their cytoplasmic bodies become less defined than before. Now the cytoplasmic network is seen to be everywhere full of this granular detritus (Fig. 3,8). In certain parts of the thymus along the border many irregular clear spaces appear, indicating that all the cells from that part have been completely absorbed in the lymph. The bundles of connective tissue fibres bounding this area have larger interspaces than elsewhere. These bundles appear to penetrate more and more into such regions.

At this stage of the thymus the red blood corpuscles (Fig. 3, I) are more numerous than before. They also undergo disintegration. Their cytoplasmic bodies become clearer, or liquefied, except a thin marginal layer. Their nuclear membranes disappear and the chromatin becomes granular. In some of them the nuclei break into fragments or larger deep-staining granules (Plate II, Fig. 3, B). Later the cytoplasmic membrane ruptures and all these gradually disappear.

At places groups of thymus cells become pycnotised and seem to undergo some chemical change on account of which they remain unaffected in various stains. These nuclei become reduced to brownish or dark granules.

In the process of general degeneration some of the reticular cells behave quite differently (Plate III, fig. 3, 3). Their cytoplasm becomes dense and reminds one of non-striated muscle-fibres. But their nuclei retain their original structure. This change is noticed in all the reticulum cells of the layer along the surface of the gland in contact with the outside connective tissue. The reticular cells bounding the connective tissue coats of blood vessels also behave similarly. Besides these, many reticular cells in the mass of the thymus also undergo this change. In a section such a cell is seen to be usually provided with a single tapering process on one side of the nucleus. In some of them the process extends on opposite sides of the nucleus and makes it resemble a muscle fibre. The processes of adjoining cells meet and form a large-meshed network round other degenerating cells. These cells appear to withstand the process of degeneration. But as the bundles of connective tissue fibres invade this part, these cells become enclosed by them and gradually shrink in their midst (Fig. 3, 10). These are described by Hammar as myoid cells and in some cases he has shown fibrillae and cross-striae in their processes. In some cases the fibrillar nature of the processes is indicated but even after fixing the thymus of the plaice in Tellyesniczky's fluid and staining the sections with Benda's crystal violet, as recommended by him, the cross-striae were not visible.

When reticular cells bounding mucus globules become myoid they resemble the corpuscles of Hassal more than before. Some of these mucus glands (Fig. 3, 5) are seen bursting open and allowing the mucus to come out.

While these changes are going on in the thymus, the surrounding connective tissue appears to be more active than before. Now it contains numerous blood vessels (fig. 3, 6). The sheet of connective tissue fibres in contact with the surface of the thymus increases in thickness and later undergoes a hyaline degeneration. Similarly the adventitia of blood-vessels also becomes active. The collagen fibres of this layer now penetrate between the muscle fibres of the wall of the blood-vessel. The substance of the muscle fibres swells and undergoes a granular degeneration. The modified cells now protrude into the cavity of the vessel, and ultimately are replaced by collagen fibres. In this way are seen in the midst of the thymus cells very characteristic figures in the form of spider's web or skein when stained blue by Mallory's connective tissue stain (Fig. 3, 4). Some of these show an advancing hyaline degeneration. The result of the thickening of the coat of connective tissue fibres round the whole of the thymus and the capillary blood vessels inside it, must be to cut off its nourishment and to hasten its degeneration. The actual advance of the collagen fibres into the original thymus area takes place in those parts where the granular or coagulum degeneration is actively taking place.

In the interior of the thymus gland some isolated collagen fibres are seen scattered amongst the reticular cells. Whether the fibroblast cells producing these reached there along the adventitia of blood capillaries or whether they are produced by the activity of the former undifferentiated fibroblast cells it is not easy to say. Similarly it is not easy to decide whether the degeneration of the thymus tissue is due to its own exhaustion or whether it is to be attributed to the activity of the surrounding connective tissue.

Although the proper thymus tissue is much reduced in this seven years old specimen its former outline is indicated as the replacing connective tissue is denser than the surrounding loose connective tissue. Judging from the activity of the process of involution in this specimen it would not be far from right to think that the thymus would completely disappear within a year or two. In a specimen 52 cm. long and at least ten years old the thymus was reduced to a vestige. It was represented by some microscopic groups of thymus cells and a few similar coagulum balls scattered in a sheaf of the bundles of connective tissue fibres. This vestige of the thymus seems to persist throughout the life of the plaice as a similar vestige was found in a plaice at least seventeen years old.

Note on the Head-Kidney.

While the thymus is vigorously growing at the beginning of its life, another growth of a similar nature takes place in its neighbourhood. It is the formation of the head-kidney in place of the larval kidney or pronephros (Text-Fig. 2). A well developed pronephros is present in the larva from the time of its hatching. In the pronephros of a newly-hatched larva the segmental duct forms a simple loop with an opening into the pronephric chamber which is a portion of the coelome cut off from the main cavity. The opening of the pronephric duct or nephrostome did not show any cilia on its rim. The wall of the pronephric chamber consists of a single layer of squamous epithelium. Into this pronephric chamber of each side the dorsal aorta sends a much-coiled capillary branch forming the glomus.

The pronephros is at the level of the thymus and is separated from it by a thick layer of connective tissue only. While the thymus cells are being differentiated and are multiplying in the thymus the simple loop of the pronephros becomes twisted and acquires two more openings into the pronephric chamber. Then the lymphocytes begin to accumulate in this region and by the time the metamorphosis of the larva is complete the glomus has disappeared, and the pronephros is replaced by a mass of lymphocytes which is known as the head-kidney in bony fishes. The cells of the head-kidney are similar to the thymus cells and moreover a trail of the thymus cells could be seen in the intervening connective tissue between these two organs in two sections of a larva eleven millimeters in length.

Note on the Thyroid.

The thyroid of the plaice, as in other vertebrates, consists of minute vesicles held together in a dense connective tissue. In the plaice it is not a well-defined gland. It forms an irregular mass situated round the ventral aorta partly behind and partly in front of the origin of the second pair of afferent branchial arteries. The vesicles are mostly spherical, some of them being oval or ellipsoid. The walls of the vesicles are formed of cubical epithelial cells. In a specimen of 30 cm. length the vesicles might be about two thousands. The diameter of the vesicles varied from ·04 mm. to ·4 mm. But in a plaice 52 cm. long and at least ten years old the thyroid appeared to be much reduced. The vesicles appeared to be reduced both in number and in size and the intervesicular connective tissue had increased and had become more fibrous than before. In a seventeen years old plaice a similar reduced thyroid was present with islands of adipose tissue in the intervesicular connective tissue.

In a plaice larva about two weeks old the thyroid consisted of three or four vesicles. The diameter of the vesicles was 16 microns. In a larva of 7·5 mm. length the number of vesicles increased to about eight, and most of them were about 20 microns in diameter. At this stage the thymus was quite rudimentary. By the time of the metamorphosis their number increased to about twenty and the maximum diameter became 120 microns.

Note on The Supra-renal Bodies.

In a preserved specimen of the plaice 29 cm. long when the body-wall over the kidney from the blind side was removed a lighter spot was seen in the substance of the kidney closely at its posterior margin. This side of the kidney was nearly straight and ran transversely to the body. The lighter spot was due to the presence of the supra-renal bodies inside. When the thin pigmented covering membrane was removed, it stood out as an oblong whitish body. It was very near the ureter of this side. It was 3 mm. long and 2 mm. broad. The supra-renal body of the other side was further embedded in the kidney and could not be seen on that surface. It was slightly in front of the other supra-renal and was nearly spherical.

In a larva of 6·5 mm. length the supra-renal body of each side was round and in close contact with the segmental duct of that side. It was situated immediately behind and above the opening of the segmental duct into the urocyst. It was enclosed in a thin membrane and its cells could be easily distinguished from the cells of the segmental duct by their smaller size and deeper staining. Though the cells had an epithelial appearance a few split-like spaces were seen among them. In the centre of the body there was a lighter space as large as one of its cells. It was filled with some mucus like substance. The body was 16 microns in diameter.

In a larva 12 mm. long the supra-renal bodies were surrounded by lymphoid tissue of the kidney on all sides except the posterior. The connective tissue capsule had become relatively thick and thus they were isolated from the surrounding kidney substance. They were spherical and about 45 microns in diameter. In this specimen both of them were situated on the left side. In a metamorphosed larva or young plaice 15 mm. long the supra-renal bodies were about 50 microns in diameter. The supra-renal of the ocular side was a little in front of the other. In a specimen 46 cm. long and five years old the supra-renal bodies were situated close together and pressing each other. The exposed lateral surface of each of them was flat and nearly circular and measured 3·5 mm. in diameter. In the seventeen years old specimen with 52 cm. length the exposed lateral surfaces of these bodies were ellipsoid and measured 3·5 mm. transversely and 3·8 mm. longitudinally. These organs seem to vary both in size and slightly in position but they continue to grow proportionately to the size of the body. Their microscopical structure did not show any change in specimens of various ages.

Note on the Pituitary body.

As described by Cole and Johnstone the pituitary body of the plaice is situated on the ventral surface of the brain in front of the finger-like saccus vasculosus situated between the lobi inferiores. In a plaice 15 cm. long it formed a solid body one millimeter in length, three-fourths of a millimeter in breadth, and one-fourth millimeter in thickness. Its section showed under the microscope the four parts, *viz.* pars tuberalis, pars anterior, pars intermedia and pars nervosa in the same order as De Beer has described in the Haddock.

In a larva 6·5 mm. long the pituitary was ·07 mm. long or 1 per cent of the total length of the body. This ratio of the pituitary to the body increased to 1·6 per cent in a 12 mm. larva as its pituitary measured ·2 mm. long. But in a plaice 15 cm. long it was only 1 mm. long and the ratio was reduced to ·7 per cent. This ratio of the length of the pituitary to the length of the fish is maintained in a plaice 46 cm. long and seven years old. In the latter the pituitary formed a kidney-shaped lobe in front of the lobi inferiores, and was 3 mm. long, and 2·5 mm. broad in its widest part. In another specimen of the same length but five years old it was 3·2 mm. broad and 2·7 mm. long. Similarly in the 17 years old and 52 cm. long specimen it measured 4 mm. transversely and 3 mm. longitudinally. It had a small rounded lobe on the ventral surface. Its sections showed under the microscope the normal structure of the organ. It seems, therefore, that its actual size and shape are variable to some extent but it continues to grow and increase in size with age.

Discussion and Conclusions.

The numerous papers written on the thymus of fishes have been recently reviewed by Deanesly (1927) and all of them have been chiefly concerned with its histogenesis. But in this series of papers an attempt is being made to study the growth of the thymus in relation to the growth of the fish, and the growth of other ductless glands. For this study the plaice provides a very suitable material as the age and the length of this fish have been correlated with a considerable measure of accuracy. Although the results of this investigation cannot be fully considered till it is complete, it will not be amiss to state here what the life-histories of the ductless glands in Plaice tend to show.

From the table on page 44 showing the relations between the lengths of the thymus and the lengths of the specimens of different ages it is clear that the thymus continues to increase in length and proportionately in size even after the first spawning in the third year of the fish. Only the rate of this growth increases upto its first spawning and then diminishes steadily and slowly till the fish becomes six or seven years old, when the involution of the thymus begins. The involution seems to be complete before the fish becomes ten years old, as in a specimen of that age the thymus was reduced to a vestige and its size was negligible. In this condition it appears to persist throughout the life of the fish and thus resembles other ductless glands.

Deanesly (1927) has concluded that the involution (of the thymus) is most probably brought about by mass emigration of thymus cells and cessation of mitosis, as suggested by Hammar. It was also thought that the involution of the Teleost thymus takes place before the fish is mature. But the life-history of the thymus in Plaice contradicts it. The chief factors in the involution of its thymus appear to be the disintegration and degeneration of thymus cells and not their mass emigration. This process of involution closely resembles the immediate effects of irradication on the thymus cells of mice as described by Deanesly (1928).

About the time the thymus is reduced the thyroid also undergoes considerable reduction and absorption by the surrounding connective tissue. The reduction of the thymus and the thyroid may indicate that the plaice becomes senile at this age. This indication becomes interesting in view of the facts that the power of fish to grow in size is not limited and that Wynne-Edwards, after having studied the body-weights, the gonad-weights and ages of about 400 mature herrings from the neighbourhood of the Isle of Man, has found that the weight of their gonads at the spawning time increased with age showing that the annual loss of tissue at spawning was completely made up during the next twelve months and that death cannot be due to the increasing tax of spawning ultimately exceeding the animal's powers of recovery. The advancing age seems to have no effect on the other ductless glands. The normal microscopical structure and the proportionate sizes of the supra-renal and pituitary bodies even in a seventeen years old plaice may indicate that they are concerned with the unlimited power of the fish to grow in size.

While the thymus gland is growing an emigration of the thymus cells has been observed in every case where its development has been studied. When the thymus was taken as the original source of the lymphocytes in the body of the fish, it was rightly suggested that the lymphocytes in the head-kidney were derived from the emigrating thymus cells (Beard). But later investigations showed the presence of lymphocytes in the body of the fish previous to the formation of the thymus gland, and naturally the lymphocytes of the head-kidney were derived from the rest of the lymphocytes. But thus the universally observed emigration of thymus cells remains quite a mystery. The trail of thymus cells from the thymus to the head-kidney across the intervening narrow partition of loose connective tissue observed in two sections of a larva of Plaice 11 mm. long strongly suggests that the emigrating thymus cells may find a new home in the degenerating pronephros.

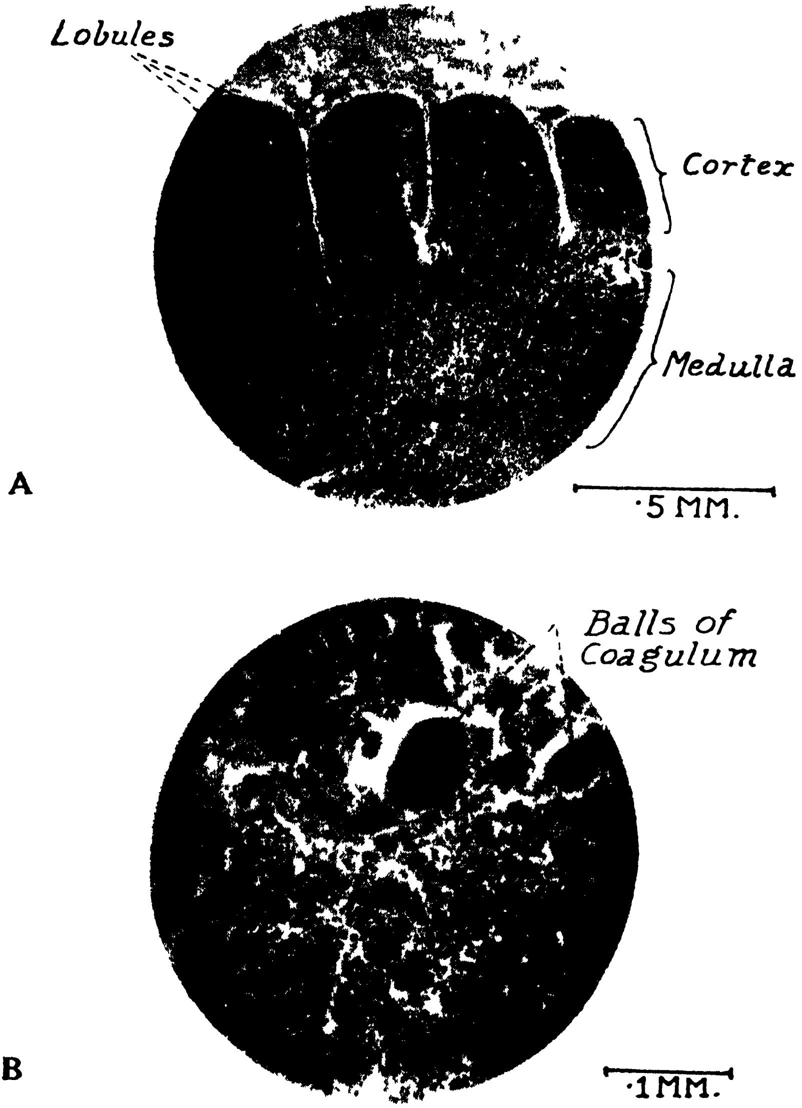
Acknowledgments.

I take this opportunity to express my best thanks to Dr. A. N. Meldrum, former Principal of the Royal Institute of Science, Bombay, for having enabled me to spend two years at Liverpool and to work on this problem. I am very sorry that Dr. J. Johnstone under whose guidance and with whose help and inspiration this investigation was carried out in the Oceanography Department of the University of Liverpool, is not living to see this completed and to receive this expression of my gratitude to him. My best thanks are also due to Dr. R. J. Daniel whose friendship and advice greatly facilitated my work and to Mr. W. C. Smith for having most willingly and readily supplied me the material.

Summary.

1. The anatomy and histology of the thymus gland in Plaice are described. Pycnotic cells, balls of coagulum and irregular spaces with varying contents are noticed in the organ as resulting from the necrobiosis of thymus cells.
2. A microscopic group of thymus cells was first noticed in a 7·5 mm. larva whose yolk must have been absorbed some weeks before. The thymus grows faster than the body in size till the first spawning in the third year of the fish. Later the gland continues to grow but its rate of growth gradually decreases till its involution begins in the sixth or the seventh year of the fish. After involution the organ seems to persist as a vestige of negligible size throughout the life of the fish.
3. The process of involution is described in detail. The chief factors in the destruction of the thymus tissue are found to be the mass disintegration and degeneration of thymus and reticular cells and not the mass emigration of thymus cells.

PLATE I FIG 1



Microphotographs of a part of a longitudinal section of the Thymus of an adult plaice A, Section seen with the low power of microscope B, Part of the same passing through Medulla seen with the high power

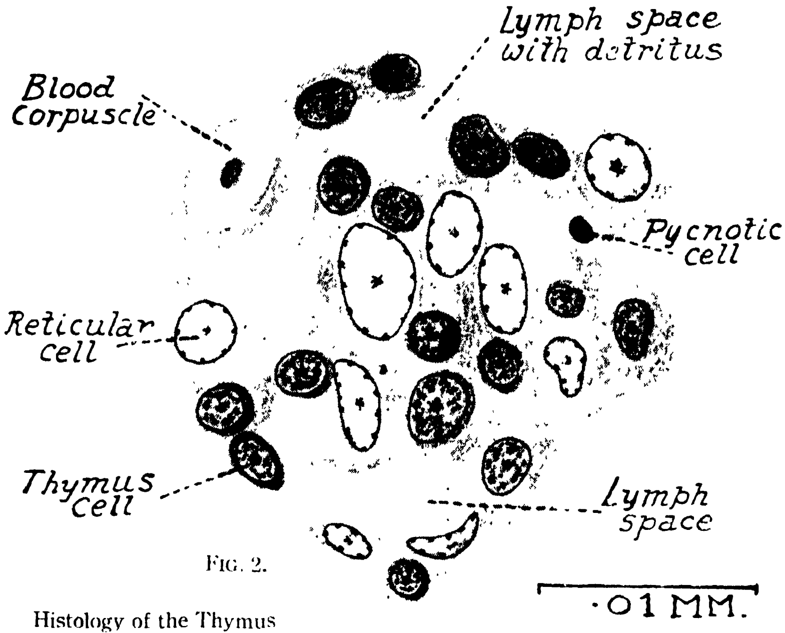


FIG. 2.

Histology of the Thymus of an adult plaice

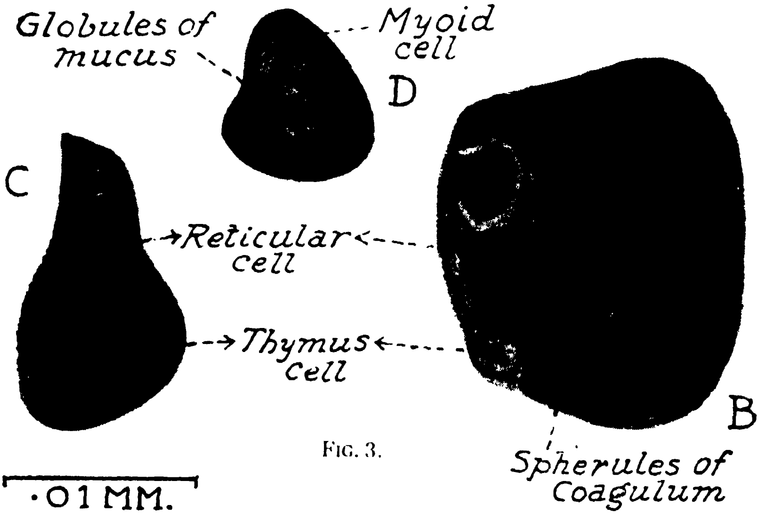
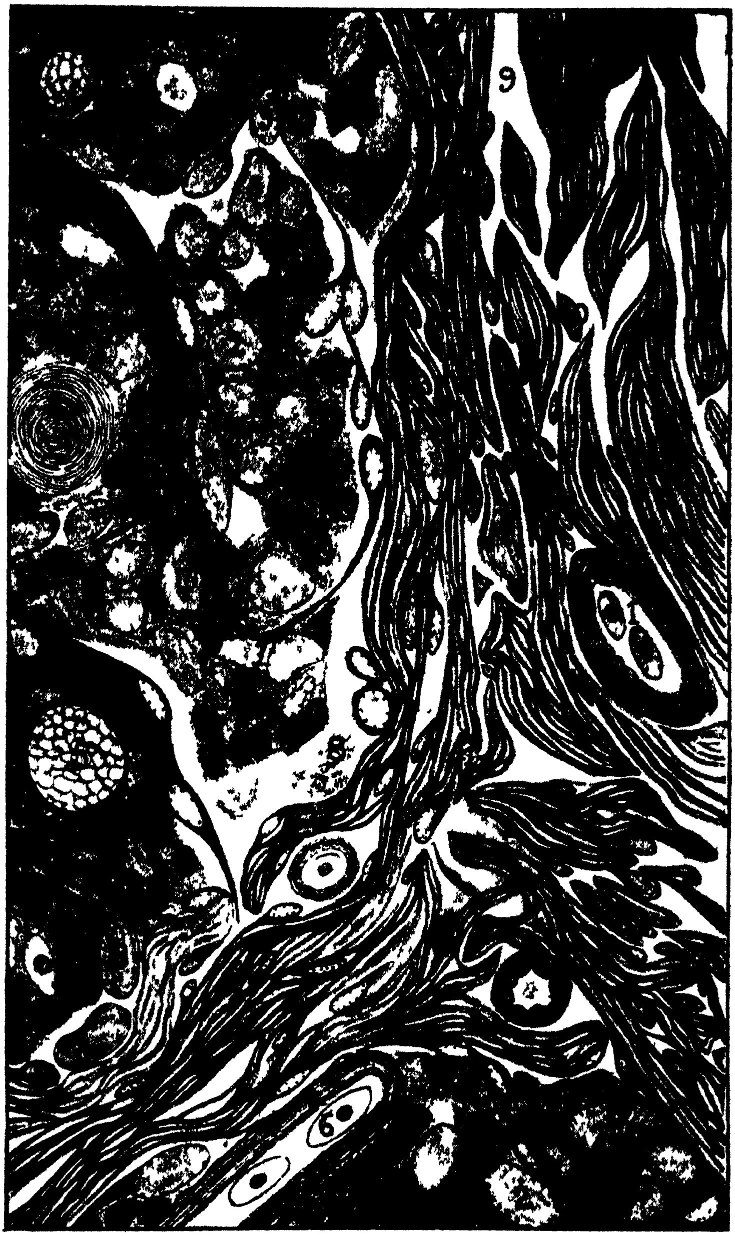


FIG. 3.

Histology of the involuting Thymus of a plaice. B, Ball of coagulum with a red blood corpuscle enclosed in its left hand upper corner. C, Reticular cell with thymus cells and spherules of coagulum. D, Myoid cell with globules of mucus.

PLATE III FIG 3 A



S.H.L. del ·01 MM.

Histology of the involuting Thymus of a plaice 1, Red blood corpuscles 2, Reticular cell 3, Myoid cell 4, Obliterated capillary blood vessel 5, Mucus gland bounded by myoid cells 6, Capillary blood vessel 7, Bundle of connective tissue fibres 8, Granular detritus 9, Lymph space 10, Reduced myoid cell

4. The thyroid is found to be considerably reduced while the thymus was rapidly disappearing. This simultaneous change in the thyroid and the thymus is suggested to be due to old age. The advancing age seems to have no effect on the pituitary and the supra-renal bodies, probably suggesting that they are concerned with the power of the fish to grow in size throughout life.
5. It is suggested that the often observed emigration of thymus cells throughout the life of the gland may be responsible for the accumulation of similar cells in the head-kidney of the Teleost.

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A SUSPECTED SOUND PRODUCING ORGAN IN EMPOASCA DEVASTANS

By

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While working out the life history and anatomy of *Empoasca devastans*, a serious pest of cotton in India, a pair of chitinous apodemes, arising from the second abdominal sternum, was noticed. These chitinous plates are situated on either side of the median line in the abdomen and extend from the second to the fourth abdominal segment. (Figure 1.) They were first noticed as two leaf-like plates in chitin preparations. In sections of the animal, the following anatomical features are discovered. The sternal plates of the third thoracic segment and the first abdominal segment are for a great part tucked in and appear almost transverse. From the junction of the hind margin of the metathoracic and the first abdominal sterna runs a pair of well developed muscles obliquely ventralwards and each of them attaches to the middle region of the apodeme of the respective side. A pair of similar muscles runs from the inner margin of each of the plates obliquely sideways and attaches itself to the ventral wall of the abdomen. The plates are concave on their dorsal and convex on their ventral side.

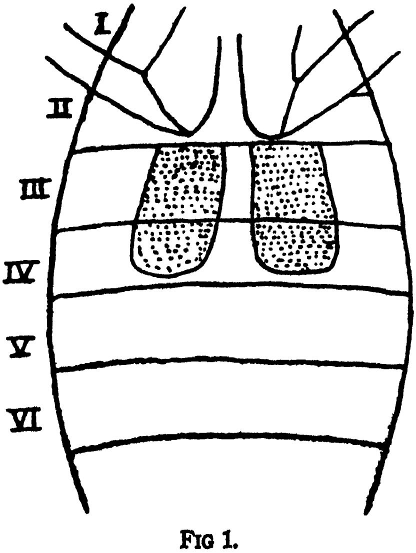

FIG 1.
Sound producing organs of Empoasca devastans, male.
(Chitin preparation)

Apparently no such plates have ever been described in any insect, and their function is not certain. Their situation, however, recalls the sound-producing organ of the Cicadidae. In the *Cicada*, the actual sound-producing organ is a fixed concavo-convex plate, the "timbal", to which attaches a strong muscle, which by its contraction and relaxation vibrates the plate, the vibration resulting in the production of a sharp sound. The situation of this plate is external in a hollow concavity on the abdominal surface. In *Empoasca devastans*, however, the plates are internal and are not fixed on all sides. The contraction of the oblique muscle, attached to the concave side of the plate, will turn the plate convex inside and concave outside. The contraction of the ventral muscles, in unison with the oblique one, will produce the same result. Possibly for a full reversion of the plate these muscles must act together. If the plate is thus turned

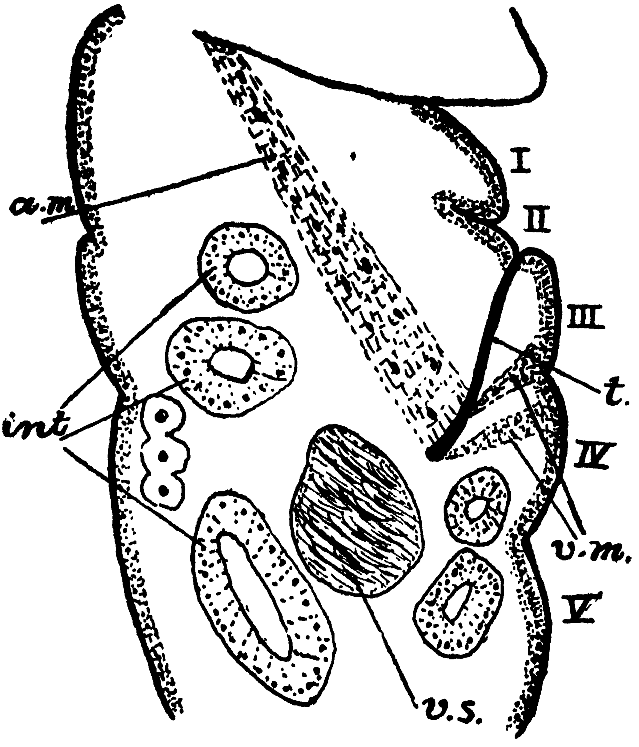

FIG 2.

Longitudinal section showing the attachment of muscles to the " timbal " in Empoasca devastans, male.

I-V = Segments of the abdomen ; *a. m.* = Dorsal muscles attached to the timbal ; *int* = Intestine *t.* = timbal plate.

v. s. = Vesicula seminalis.

v. m. = Ventral muscles attached to the timbal.

suddenly from concave to convex, and convex to concave, from the nature of the chitin a smart clicking sound ought to result. In fact the same process is exactly what happens in the *Cicada*, with the difference that elaborate structures are associated with the apparatus for intensification of sound in that insect.

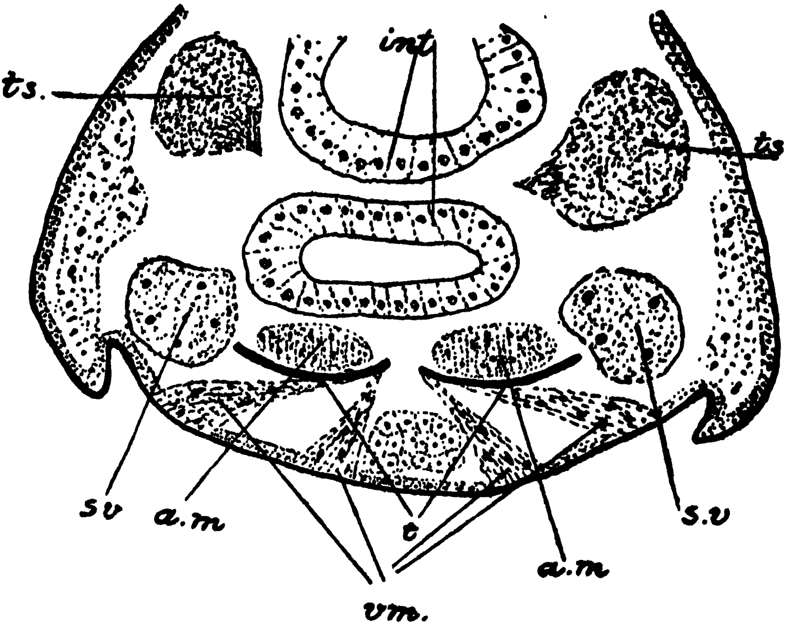

FIG. 3.

Transverse Section showing the arrangement of muscles of the timbal in Empoasca devastans, male.
ts = Testis.
S. V. = Pseudo vitellus.
Other letters same as in Fig 3.

As in the *Cicada*, these organs are limited to the male. From observations made on the living insects, it is found that a sharp sound is often produced by the male. It is therefore reasonable to assume that the sound originates from the plates. Further investigations with the aid of a microphone are however necessary to confirm the tentative conclusions arrived at. Kirkaldy (1907) states that some species of leaf-hoppers are capable of producing sound, but he was unable to trace whence the sound actually emanated. I have observed similar plates in another Typhlocybid also, an undescribed species, but the plates appear longer in this insect. (Fig. 4). Proper examination may reveal a number of species possessing these organs.

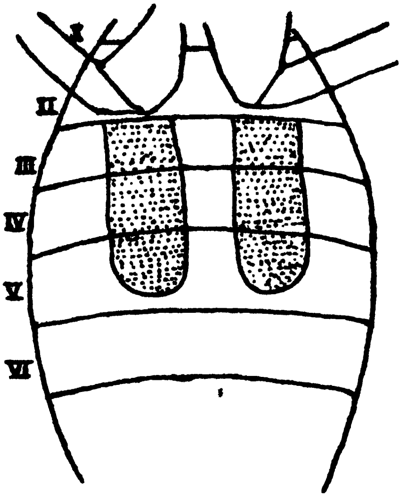

FIG. 4.
Sound producing organs of an undescribed species of Typhlocybidae (Chitin praparation)

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EXCRETION IN MELIPONA DURING METAMORPHOSIS

By

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While working out the metamorphosis of *Melipona irridipennis*, a group of large opaque cells visible to the naked eye were noticed in preserved specimens of late larvae and pupae. Examination showed that they are imbedded amongst the fat cells and are limited to the abdominal region. They are not found in the feeding larvae, but make their appearance only after the larvae defaecate. In the young adult they aggregate together and eventually disintegrate. In sections, these cells exhibit a circular outline and are easily distinguished from the hexagonal or square shaped fat cells. Each cell has an abundant

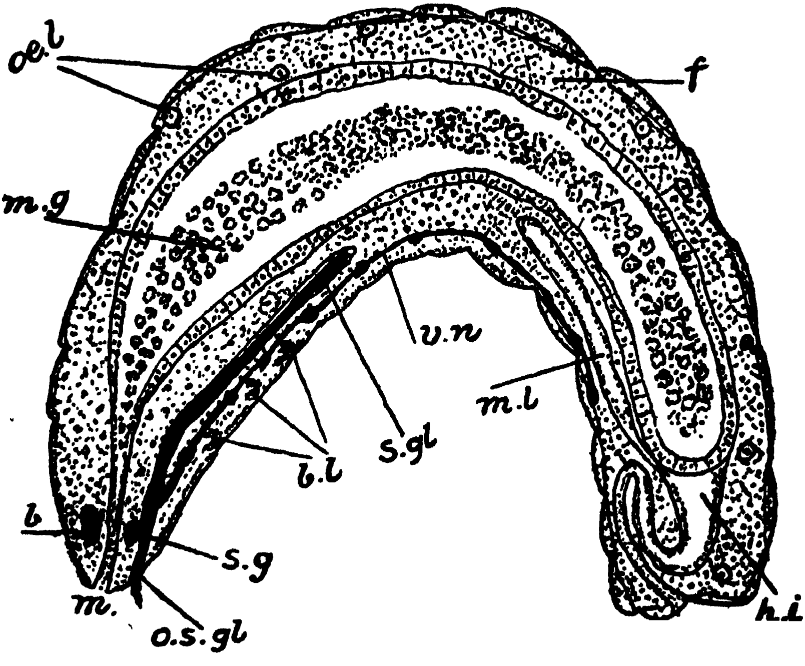

FIG. 1. Longitudinal Vertical Section of a full grown larva.

b. = brain of larva.
f. = fat body.
m. = mouth.
m. l. = malpighian tubules of the larva.
Oe.l. = oenocytes of the larva.
O.S.gl. = opening of the salivary glands.
b. l. = imaginal buds of legs.
h. i. = hind intestine.
m. g. = mid-gut.
S.gl. = Salivary glands.
v.n. = Ventricle Nerve cord.

cytoplasmic area and a fairly conspicuous central nucleus. When stained with Mallory's triple stain, Ehrlich's Acid Haematoxylin, or Woodland's Picro-Indigo-Carmine, the nucleus absorbs a red colour, whereas the cytoplasm remains unstained. The cytoplasm is studded with small round refractive inclusions. The appearance of these inclusions suggests that they are excretory products. Dr. Keilin of the Molteno Research Laboratory, Cambridge, who has been kind enough to examine my slides, is also of opinion that these are excretory products. Such cells have not so far been described from any insect. On account of their strong resemblance to the nephrocytes and in view of their function, I have termed them *Pro-nephrocytes.*

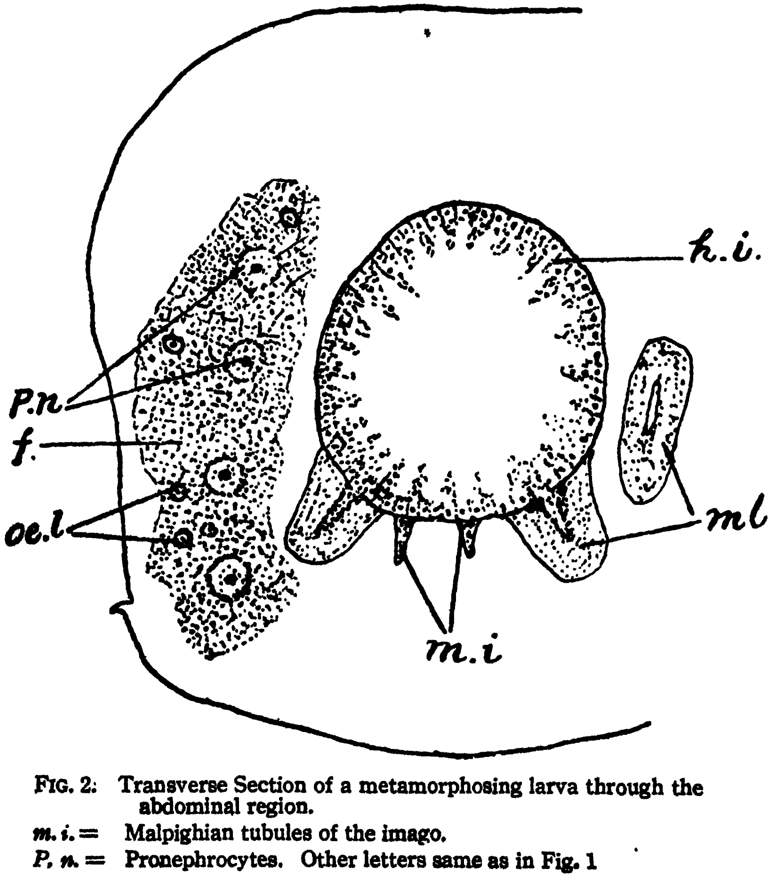

FIG. 2: Transverse Section of a metamorphosing larva through the abdominal region.
m. i. = Malpighian tubules of the imago.
P, n. = Pronephrocytes. Other letters same as in Fig. 1

In Hymenopterous larvae, the mid-gut and the hind-gut are blind tubes abutting one against the other and only at the beginning of the metamorphosis communication between the two is established. Nelson (Science Vol. IV, p. 927) has shown that at the same time as the opening of the mid-gut into the hind, the malpighian tubules which in the larvae are closed, come to open into the hind-gut, so as to empty their contents into the latter. Soon after defaecation the larval malpighian tubules undergo complete histolysis. The adult tubules arise as outgrowths from the regenerated hind-gut.

There is no doubt that during metamorphosis intense metabolism is taking place in the tissues. As a natural result excretory products are thrown into the blood in abundance. The presence of these excretory substances will interfere with the rebuilding of the tissues and in the best interest of the developing organs, they should be removed from the sphere of action.

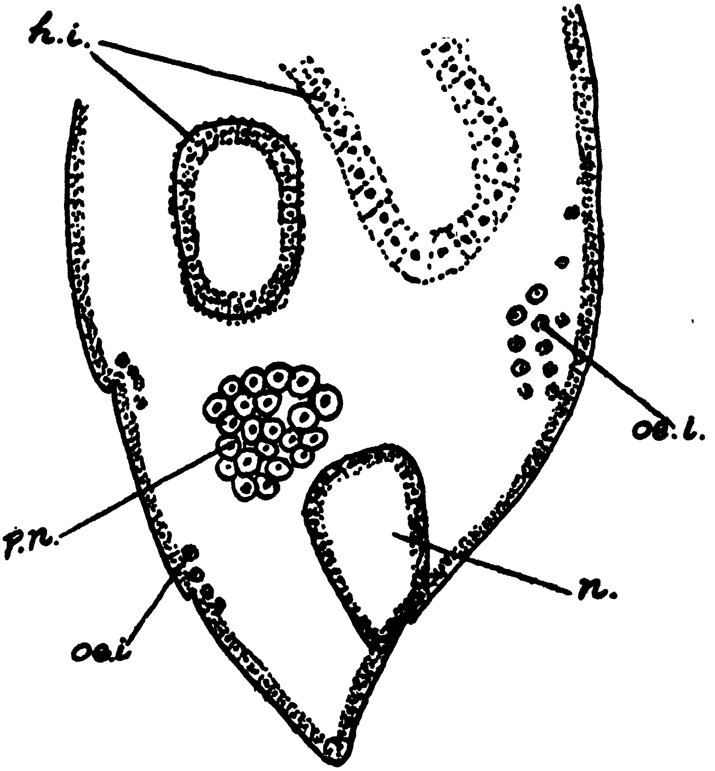

FIG. 3. Longitudinal Vertical Section through the abdominal region of a newly hatched adult.

oe. i = oenocytes of the imago;
Other letters same as in Fig. 1.

The fat body in addition to the storing of albuminoids and fats is generally understood to perform some excretory function amongst metamorphosing insects. Perez, Keilin, and others have noted urates and calcareous products in the cytoplasm of fat cells. In the Melipona larva, however, the whole fat body as such undergoes complete histolysis and that tissue will not be available to store up the waste materials. Some of the fat cells are therefore specially called in to perform that function at this critical time. They do not share the histolysis; on the other hand, their cytoplasm becomes enlarged with the enormous quantity of waste material taken in.

Apparently other investigators have noted these cells in other Hymenoptera but possibly confused them with oenocytes. Karawaiew in Lasius describes a group of large phagocytes. From his description I believe them to be of the same kind as pro-nephrocytes. I have not however observed any phagocytic tendency amongst these cells in Melipona. The appearance of such special cells during the prepupal stage and their disintegration in the adult and the presence of excretory products in the cytoplasm, could lead only to one conclusion, namely that they are specialized cells called in at the intervel between the histolysis of the larval malpighian tubules and the appearance of the imaginal ones, to perform the vital function of excretion.

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A SHORT ACCOUNT OF THE VENOUS SYSTEM IN ONCIDIUM Verraculatum (Cuv.).

By

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While going through the literature on the subject of circulation of blood in Oncididae, it has been found that the arterial system alone of Oncidium verraculatum has been worked out by Plate (2) in the years 1892-94 but with regard to the venous system nobody appears to have described it uptil now.

At the end of the description of the arterial system, Plate agrees with Joyeux-Laffuie by saying " Hinsichtlich des Venensystems kannich den von Joyeux-Laffuie gemachten Angaben nights neues hinzufugen und Verweise desalb auf dessen Arbeit " and omits the description of the venous system of Oncidium from his paper. He appears to consider, therefore, that the venous system in this animal is similar to that of the species of Oncidiella described by Joyeux-Laffuie.

It is maintained in this paper, however, that this system in Oncidium verraculatum is totally different from that described by Joyeux-Laffuie. (1).

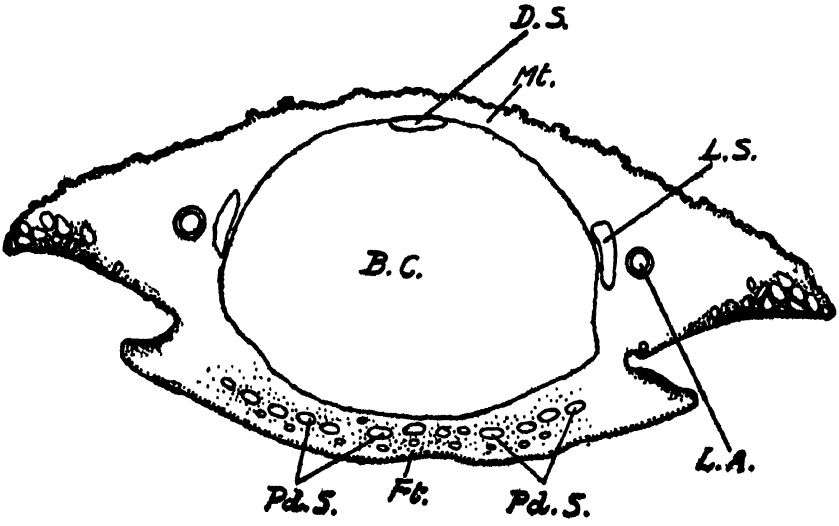


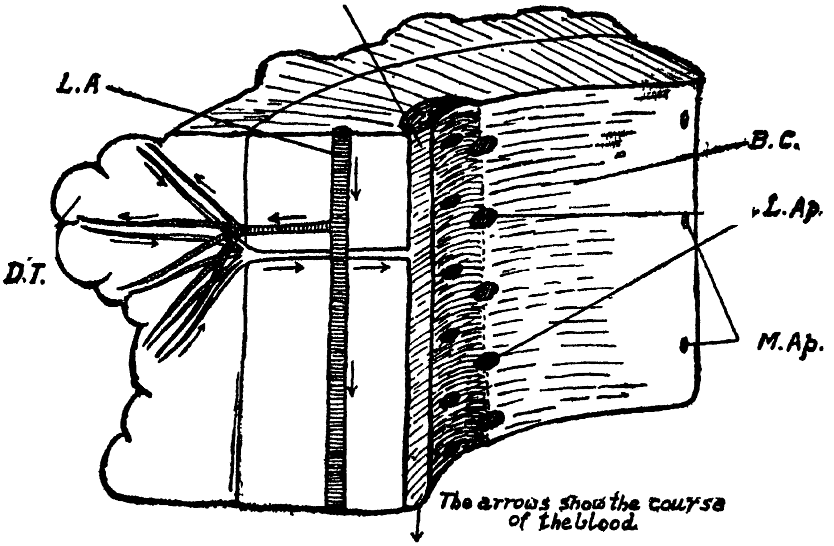
FIG. 1 Transverse section of Oncidium ×80 sinus.
B. C. = Body cavity; *D. S.* = Dorsal; *Ft.* = Foot; *L. A.* = Longitudinal artery; *L. S.* = Lateral Sinus; *Mt.* = Mantle; *Pd. S.* = Pedal Sinuses.

The venous system in this animal is described under the following heads:—

1. The Body cavity. (Figs. 1 & 2) It is a haemocoele and forms the main reservoir into which flows the blood from the great mass of the visceral structures and the reproductive organs previously supplied with the arterial blood. This body cavity takes therefore the place of capillaries between the arteries and the veins.

The venous blood runs from this cavity into two lateral sinuses situated one on each of its sides and into the pedal sinus of the foot.

2. The lateral sinuses. (Figs. 1, 2). They are placed as mentioned above, one on each side of the body cavity. They, however, take



The arrows show the course of the blood

FIG. 2.

Diagrammatic representation of the circulation of the blood from the body cavity. *D. T.*=Dorsal tubercle; *L.Ap.*=Lateral apertures; *M.Ap.*=Median apertures. Other letters same as in Fig. 1

their origin from the latter at the extreme anterior end of the same but later on they become separate from the body cavity as they proceed towards the posterior side of the animal. They are embedded on their way in the tissue of the border of the mantle.

The blood from the body cavity flows into these sinuses through a series of apertures which are placed slantwise on the wall dividing the body cavity from the sinuses.

Towards the posterior end of the animal, each lateral sinus divides into two unequal branches at the place where the diaphragm separates the body cavity from the pneumo-nephridial chamber. Of these branches the bigger ones of each side enter the lung tissue of the lung cavity, passing on their way through a part of the nephridial tissue of the respective side.

The bigger branch of the left lateral sinus runs underneath the ureter and is continued into the pulmonary vessel which runs on the dorsal side of the lung cavity and just beneath the mantle.

The course of the right lateral sinus is bent inwards at the place where the heart is situated and its bigger branch is likewise continued into the smaller pulmonary vessel.

The smaller branches of both the lateral sinuses enter the nephridial tissue and break up there into minute irregular sinuses which form a network round about the nephridial tubules.

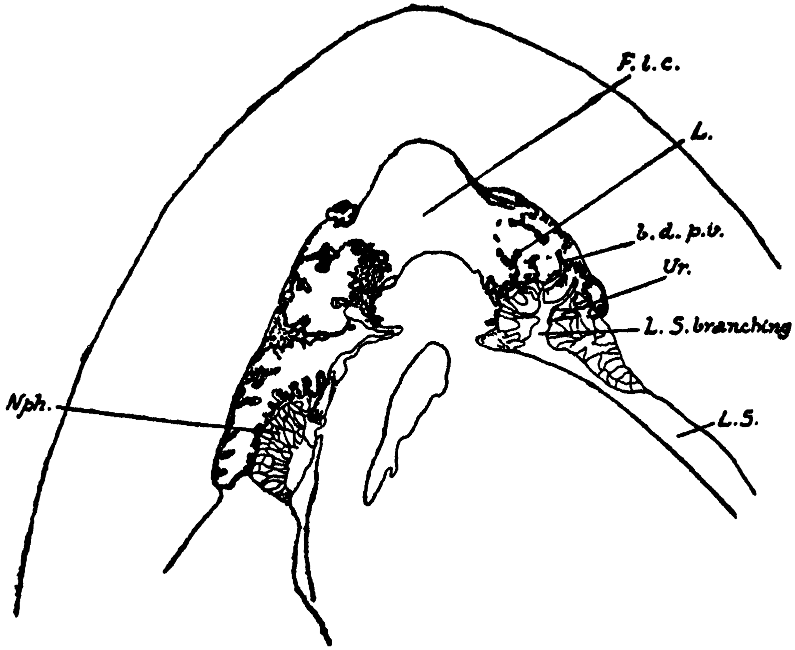


FIG. 3.

Horizontal Section of the posterior region of oncidium verraculatum × 80.
b.d.p.v: = beginning of the dorsal pulmonary vein ; *L.* = Lung tissue ; *F.l.c.* = floor of the lung cavity ; *L.S.* = Lateral Sinus ; *L.S. branching* = Lateral Sinus branching ; *Nph.* = Nephridial tissue ; *Ur.* = Ureter.

The blood from two other sources besides that from the body cavity flows into the lateral sinuses of both the sides. They are :—

(a) Blood from the foot.

The foot consists of a spongy tissue which encloses many small sinuses. The latter run into each other to form two common sinuses one on each side. That on the left opens into the left and that on the right into the right lateral sinus before each of them divides into two unequal branches as mentioned above.

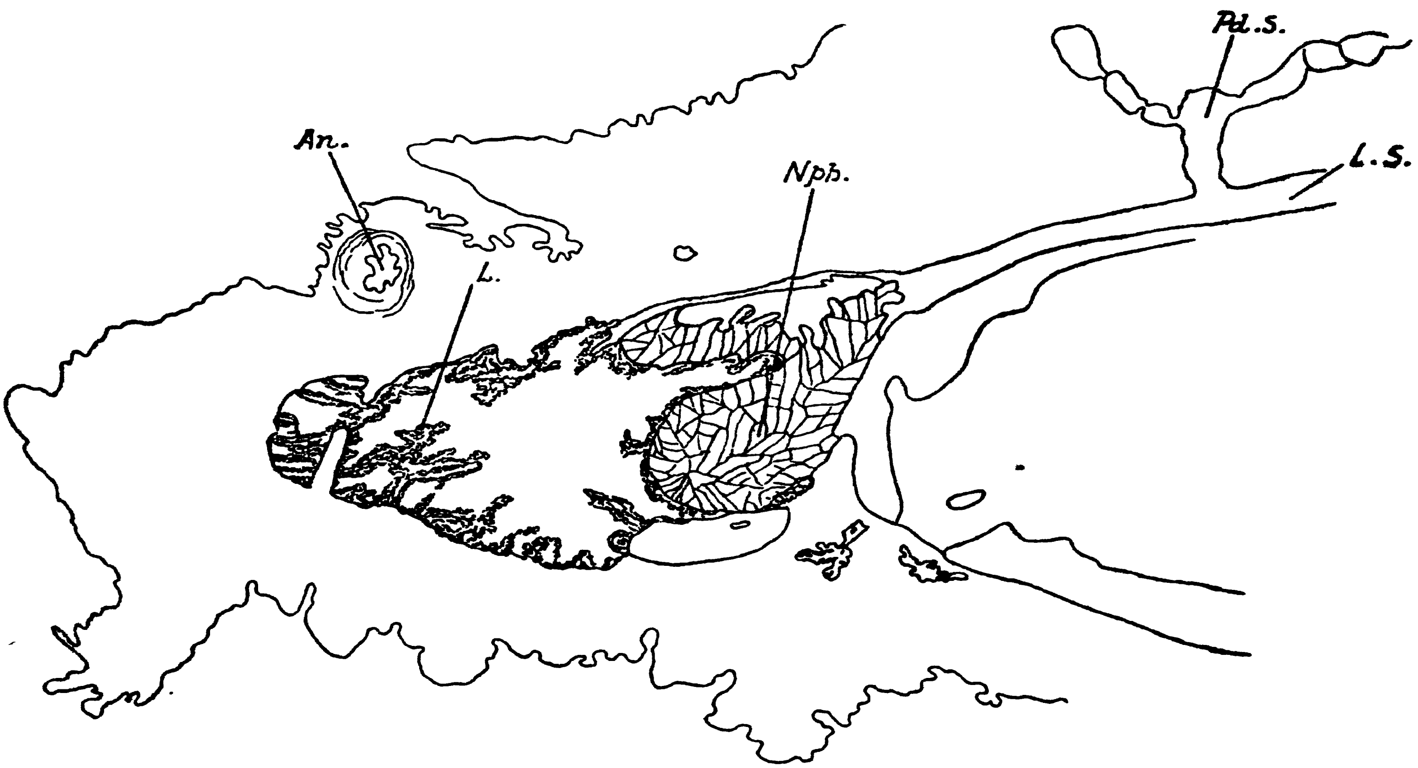


FIG. 4.
Longitudinal Section of the posterior region of oncidium verraculatum, showing the opening of the pedal sinus into the lateral sinus.
Pd.S. = Pedal sinus; *An.* = Anus. Other Letters same as in Fig. 3

(b) Blood from the mantle. (Fig. 2). All along the course of each lateral sinus a series of vessels open into it. They bring blood from the tubercles situated on the dorsal side of the mantle which are previously supplied with the arterial blood from the longitudinal artery of each side. These tubercles, it appears, act as accessory respiratory structures when the animal is submerged into water.

3. The pedal sinuses. They are found along the ventral margin of the body cavity. The blood from the latter flows into them through a series of minute apertures situated along the mid-ventral line on the floor of the body cavity. These sinuses ramify into numerous branches in the foot and run through the spongy tissue of the latter.

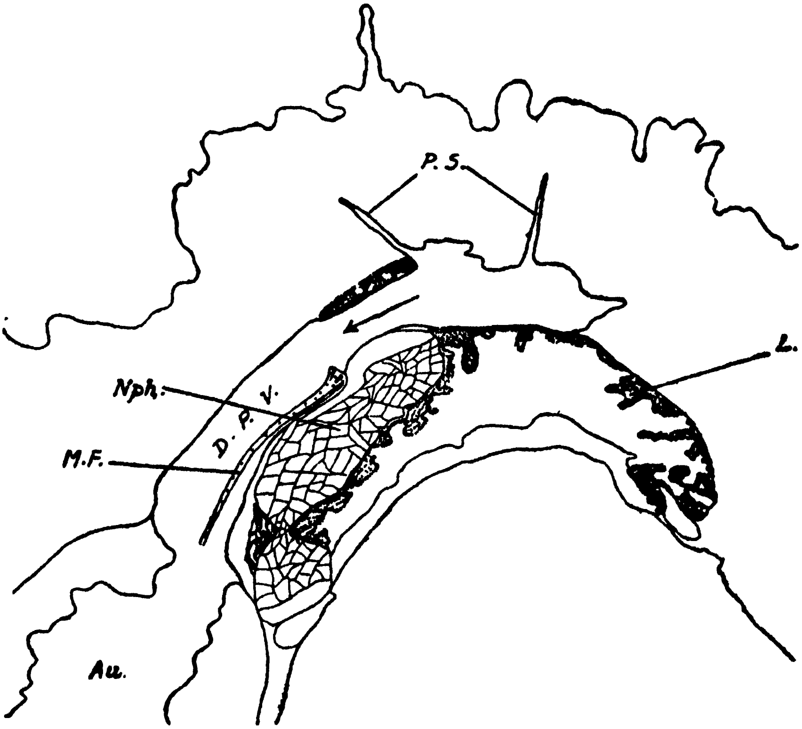


FIG. 5.
Horizontal Section of the posterior region of oncidium verraculatum. showing posterior sinuses.
Au = auricle ; *D.P.V.* = Dorsal pulmonary vein ;
M.F. = muscle fibre ; *P.S.* = Posterior sinus.
Other letters same as in fig. 3.

The blood is partly returned into the body cavity when the animal contracts and partly flows into the lateral sinuses through the common pedal sinuses as described above.

4 The pulmonary vessels. There are two pulmonary vessels of unequal lengths. One of them which is a continuation of the bigger

branch of the left lateral sinus runs along the dorso-posterior side of the lung cavity just below the mantle and opens at the right end into. the auricle. This pulmonary vessel may therefore be called the dorsal pulmonary vessel.

The other pulmonary vessel which is shorter and smaller and is similarly a continuation of one of the branches of the right lateral sinus lies on the ventro-anterior side of the lung chamber and may be called the ventral pulmonary vessel.

Both these pulmonary vessels open into the auricle at the same place but one over the other. Through the openings of both of them pass inwards into them from the auricle two muscle fibres one in each vessel which are attached to their insides.

Into these pulmonary vessels open the following :—

(a) The dorsal sinus. (Fig. 1) This dorsal sinus is situated along the mid-dorsal region of the body cavity all along its length. At several places small sinuses coming from the dorsal part of the mantle, appear to open into it. Beyond the diaphragm which separates the body cavity from the nephridial chamber, this dorsal sinus breaks into two branches one of which goes to the dorsal pulmonary vessel and the other to the ventral.

(b) The inter-nephridial sinuses. (Figs. 6 & 7). As already described, the smaller branch of each of the lateral sinus breaks within the nephridial tissue into minute vessels which surround nephridial tubules. In a transverse section the networks of the internephridial vessels can be distinguished from that of the nephridial tubules by the presence in the latter of an epithelium of flat cells with nuclei and its absence in the former. These internephridial vessels ultimately run into a series of common sinuses at different points along the outer extremity of the nephridium lying in close contact with the lung. These sinuses open into the pulmonary vessels after passing through the lung tissue for a longer or shorter distance.

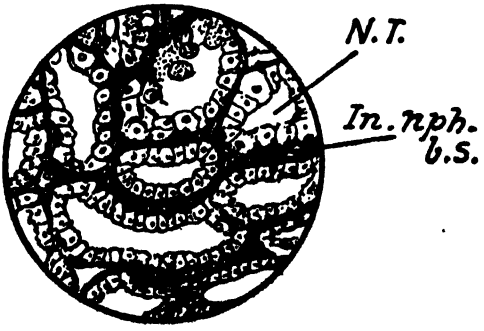


FIG. 6.
Transverse Section of the Nephridial tubules×400
In.nph.b.s. = Inter nephridial blood sinus.
N.T. = Nephridial tubule.

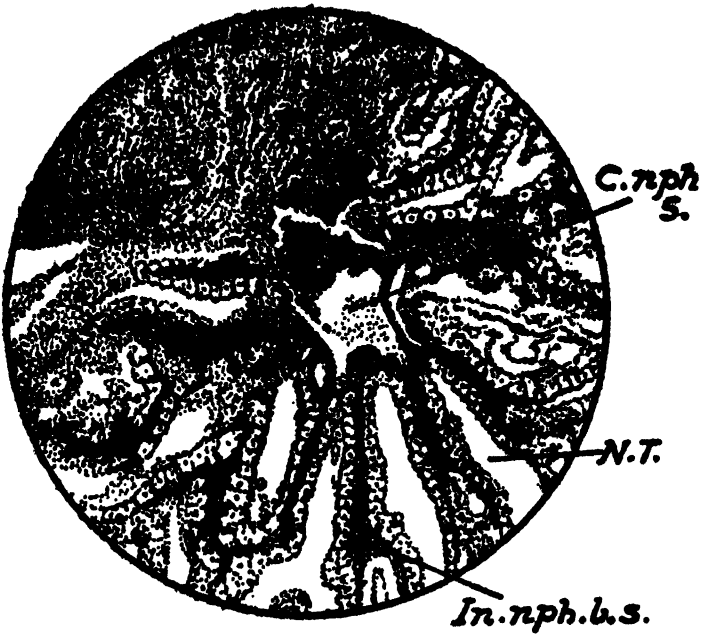
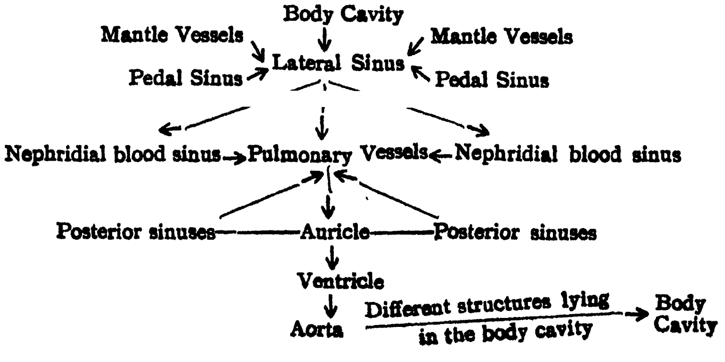


FIG. 7.
Transverse Section of the Nephridial tissue×400.
C.nph.S. = Common nephridial sinus;
Other letters same as in Fig. 6.

(c) The posterior sinuses. (Fig. 5) These posterior sinuses come from the region situated between the extreme posterior end of the animal and the lung cavity. They bring blood from the dorsal tubercles which are highly developed at this end and open into the dorsal pulmonary vessel at different points all along its course, one or two of these posterior sinuses open even into the auricle itself showing thereby that the latter structure is nothing but a dilatation of the dorsal pulmonary vessel.

Summary. The following diagram will clearly show the course of the venous blood through the animal.



Discussion. The circulation of the venous blood has been worked out in some of the species of Oncidiella, by Joyeux-Laffuie and Watson (3). At the time when Joyeux-Laffuie worked on his species the presence of the lung as separate from the nephridium was not admitted and the recognition of any pulmonary vessels was therefore impossible. According to this writer the lateral sinuses give branches to the dorsal tubercles which form the chief respiratory structures. From them the blood which is now purified, is collected into the longitudinal vessel of each side running parallel to the lateral sinus. These longitudinal vessels open ultimately into the auricle. It is therefore named by this writer "Branchio-cardiac" vessel, since it connects the branchie *i. e.*, the dorsal tubercles, with the heart.

Long before Watson had described the blood circulation in one of his species of Oncidiella, the lung and the nephridium came to be recognized as two separate structures and he therefore described the pulmonary vessels as additional structures in his species. According to him the lung becomes the primary respiratory organ while the dorsal tubercles form accessory structures for respiration. In other respects his description of the venous system is identical with that given by Joyeux-Laffuie. The longitudinal vessel is continued into the pulmonary vein of each side.

In Oncidium verraculatum however the course of the venous blood is quite different. The dorsal tubercles are supplied with blood from the longitudinal vessel which is an artery and not a vein as supposed by Joyeux-Laffuie and Watson. The vessels from the dorsal tubercles on the other hand open into each of the lateral sinuses which carry the blood directly into the pulmonary vessels of the lung cavity.

That the longitudinal vessel of Watson or the branchio-cardiae vessel of Joyeux-Laffuie is not a vein but that it is one of the important arteries, will be discussed in a separate paper.

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THE LONGITUDINAL VESSEL IN ONCIDIUM VERRACULATUM. (CUV.) IS IT AN ARTERY OR A VEIN?

By

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Plate (2) has described the arterial system in Oncidium verraculatum. He has, however, missed the true nature of the longitudinal vessel, since he has entirely agreed with Joyeux Laffuie in his (latter's) description of the venous system and the latter considers this vessel as one of the veins and names it as Branchio-cardiac vein. It is therefore very probable that Plate also thinks this vessel to be a vein.

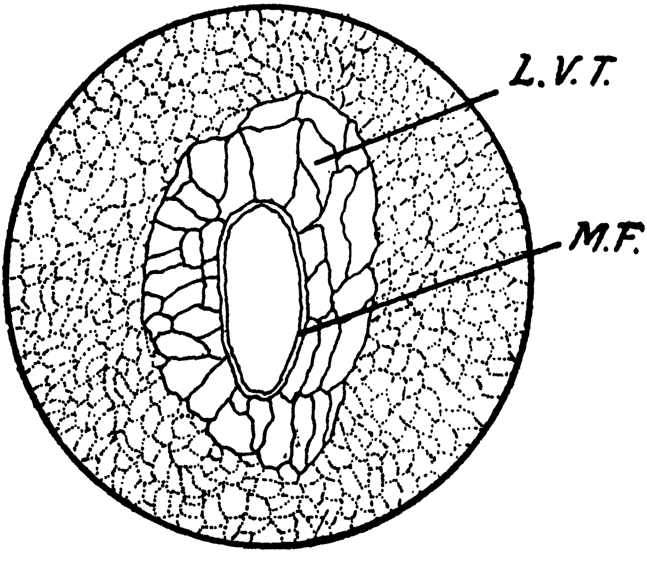

Fig. 1. Transverse Section of an artery ×200.
L.V.T. = Layer of vacuolated tissue; *M.F.* = Muscle fibre.

To do him justice, however, the root of this vessel has been figured and named by him as Parietal vessel but no further description is to be found in the text of his paper.

It will be shown in this paper that this vessel in question is not a vein as described or understood by previous writers, but, it is, on the contrary, one of the important arteries given off on either side from the main trunk of the aorta when the latter divides itself into several branches after reaching the supra and suboesophageal ganglionic nerve mass.

That this vessel is an artery can be proved by the following facts:—

(1) In Onchididae "the aorta and the principal arteries are surrounded by a thick layer of vacuolated tissue within which there is a thin layer of muscle fibres". (Watson). In cross sections of the animal, arteries can be clearly distinguished from veins by the presence in the former and the absence in the latter of this characteristic layer. In the vessel in question this layer is present throughout its whole course. Even its smallest branches show this structure; (fig 1).

(2) In a series of transverse sections this vessel can be definitely traced to its origin from the main aortic trunk; (fig 2).

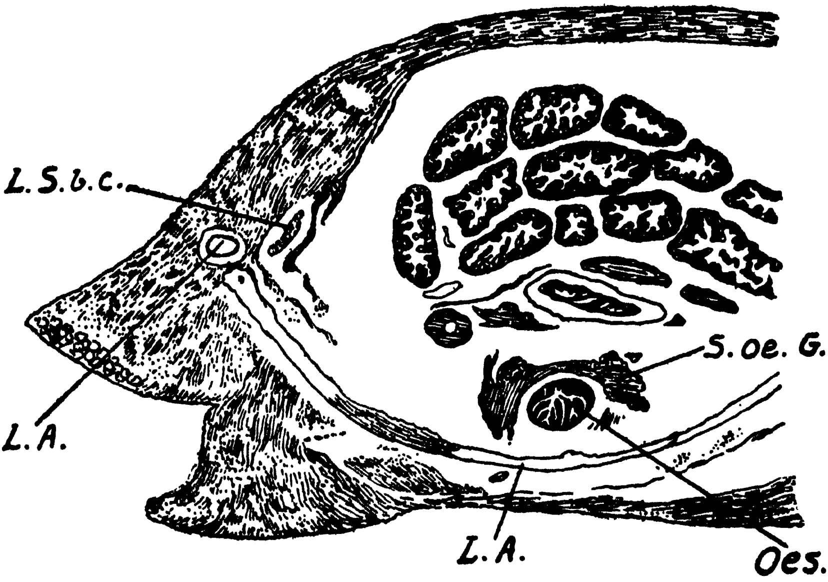

Fig. 2. Reconstruction from a Series of Transverse Sections.
L.A. = Longitudinal artery; *L.S.b.c.* = Lateral Sinus communicating with the body cavity; *OeS.* = Oesophagas; *S.oe.G.* = Supra oesophageal Ganglia.

(3) And lastly injections also prove the same fact. All the main arteries and their branches can be injected with a coloured fluid through the ventricle. The longitudinal vessel and its branches are similarly injected and the whole of its course is then made clear.

The course of the Longitudinal artery. (fig 3) This longitudinal or parietal (according to Plate) artery enters on each side, the border of the mantle after passing underneath the lateral sinus of that side. It then bifurcates into two branches, one of them going to the anterior end of the animal and the other to the posterior. Towards the posterior end the posterior branch of this artery runs parallel with the lateral sinus upto a certain distance when the latter turns inward to open into the lung cavity. The former, on the other hand, continues its course onward, following the outer curve of the lung. It then

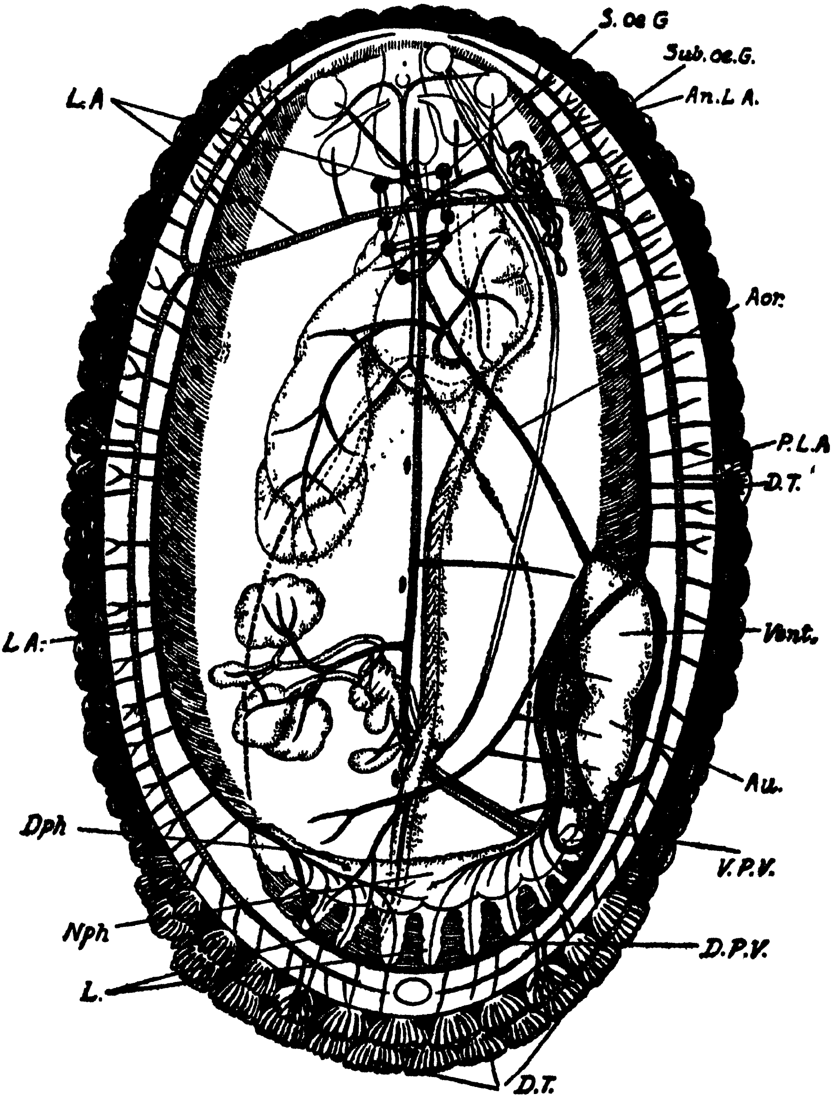

Fig. 3. Dissection showing the circulation of blood. Crossed lines represent arteries and solid black veins.

An.L.A. = Anterior branch of Longitudinal artery; *Aor* = Aorta; *Au* = Auricle; *Dph* = Diaphragm; *D.T.* = Dorsal tubercles; *D.P.V.* = Dorsal pulmonary Vein; *L*, = Lung, Tissue; *L.A.* = Longitudinal artery; *L.S.* = Lateral Sinus; *Nph.* = Nephridial tissue; *P.L.A* = Posterior branch of the longitudinal artery; *S.oe.G.* = Supra Oesophageal ganglia; *Sub.oe.G* = Sub Oesophageal ganglia; *Vent.* = Ventricle; *V.P.V.* = Ventral pulmonary Vein.

supplies the aerated blood to the area lying between the lung on one hand and the outer margin of the animal on the other.

The anterior branch of this artery carries the aerated blood to the anterior portion of the mantle.

This longitudinal artery thus supplies the aerated blood to the whole of the mantle area.

Discussion: It appears that Joyeux-Laffuie (1) and Watson (3) have not recognised the true nature of this vessel since both of them have taken it to be one of the veins in their description of the venous system of certain species of Oncidiella. The former worker calls it the Branchio-cardiac vessel, while the latter, the Longitudinal vein. In this connection it seems proper to mention that Joyeux-Laffuie is surprised to find that the mantle, though an important structure of a pulpy, thick and voluminous nature, does not receive even a small artery. This anomaly can now be explained away by recognising the fact that this vessel is an artery and not a vein and that all the vessels supposed to be opening into it are really branches of this artery going towards the mantle, to supply it with the arterial blood.

It has been shown in this paper as described above that the longitudinal vessel in Oncidium verraculatum is an artery and not a vein, and that it supplies the aerated blood to the mantle tissue through a series of small branches.

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2. Plate. L.
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} Same as in the last paper.

STUDIES IN INDIAN PUFFERS OR GLOBE-FISHES:

I. THE ENDO-SKELETON OF TETRŌDON OBLONGUS-Bloch

By

Prof. P. R. AWATI, & D. WAMAN BAL.

The endo-skeleton of Tetrodon oblongus can be divided into an axial and an appendicular part. Each part consists of the following elements :—

- (I) THE AXIAL SKELETON :—
  - (A) *Vertebral Column* :—
    - (i) Trunk vertebrae.
    - (ii) Caudal vertebrae.
  - (B) *Skull* :—
    - (i) Cranium :—
    - (ii) Sense capsules.
    - (iii) Visceral Skeleton :
      - (a) Palato-Pterygoid Bar.
      - (b) Suspensorium.
      - (c) Jaws.
      - (d) Hyoid Arch.
      - (e) Branchial Arches.
      - (f) Opercular bones.
- (II) APPENDICULAR SKELETON :—
  - (A) Pectoral Girdle.
  - (B) Fins :—
    - (a) Pectoral Fin.
    - (b) Dorsal Fin.
    - (c) Ventral Fin.
    - (d) Caudal Fin.

(I) THE AXIAL SKELETION :—

(A) *Vertebral Column.*—The vertebral column (Figs. 1, 2, 3, 4, and 5) of this fish consists of only a small number of vertebrae, namely, twenty as denoted by Roman numbers in the figure. They are completely ossified. The centrum is biconcave or deeply hollowed out at both ends and hence is amphicoelous. The notochord which is continuous from one end of the vertebral column to the other is strongly constricted at regular intervals in the mid-region of the centrum *i. e.* intravertebrally but it is greatly dilated intervertebrally (6). The edges of the

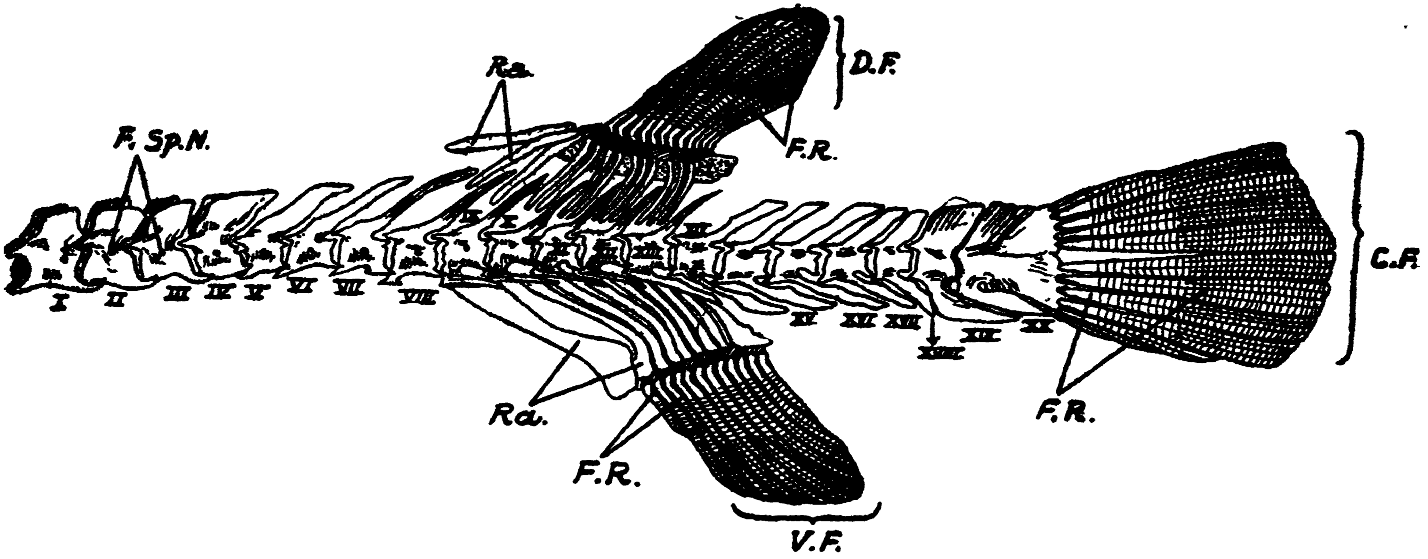

Fig. 1. Lateral view of the vertebral column with the skeleton of the Dorsal, Ventral and Caudal fins.

C.F. = Caudal Fin; *D.F.* = Dorsal Fin; *F.R.* = Fin Rays; *F.Sp.N.* = Foramen of spinal nerves; *Ra.* = Radial; *V.F.* = Ventral fin; I to XX Vertebrae.

succeeding and preceding centra are united by a ligament and the biconcave spaces between them are then filled in by the gelatinous remains of the notochord. The vertebral column terminates at the end of the tail. It is found after minute examination that the vertebral column with the notochord is slightly bent dorsalwards at the extreme end of the tail.

The vertebral column cannot be divided into several regions owing to more or less uniform character of its elements. It can, however be grossly divided into two regions only—the trunk region and the caudal. The vertebrae of the trunk region have neural arches and neural spines only, while the caudal ones have haemal arches and haemal spines in addition to the neural arches and spines. The roots of the different spinal nerves make their exit through a minute foramen in each neural process of the Vertebra.

(*i*) *The Trunk Vertebrae*:—

There are eight amphicoelous trunk vertebrae, out of which first four are larger than the last four. From each centrum arise dorsally two lateral neural processes, which meet above in the middle and form the neural arch. The latter encloses the neural canal through which passes the spinal cord. The neural arch is continued above into the neural spine directed upwards and backwards. The neural arches of the first three vertebrae are incomplete owing to the fact that the neural processes do not meet each other in the centre. Each limb of the arch is however continued above into its own neural spine. This structure, *i.e.*, the incomplete arch carrying two spines is described by Rosen (11) as "Spina Bifida" (Figs, 1, 2, 3, and 4). The neural canal which is thus left incomplete is however closed by a ligament. The neural spines of each side which are vertical and flattened from side to side and elongated antero-posteriorly, are found almost touching in such a way that a continuous wall is formed on that side. A deep elongated groove is thus enclosed within these two walls. This groove is open at the anterior end but is closed posteriorly by the boat-shaped neural spine of the fourth vertebra. The supra-occipital spine is embedded in the longitudinal muscles contained in this groove. The contraction of these muscles straightens the vertebral column when arched (bent) in the act of inflation. The neural arches and spines of the fifth, sixth, seventh and eighth vertebrae present no peculiarities. Their spines are, however, reduced in size from before backwards.

The centrum of the first vertebra or the atlas articulates with the single occipital condyle on the basi-occipital by means of a ligament. This articulation of the vertebral column with the skull is further strengthened by the paired elongated facets on the ex-occipitals into which fit the corresponding processes (*i. e.* pre-zygapophyses) of

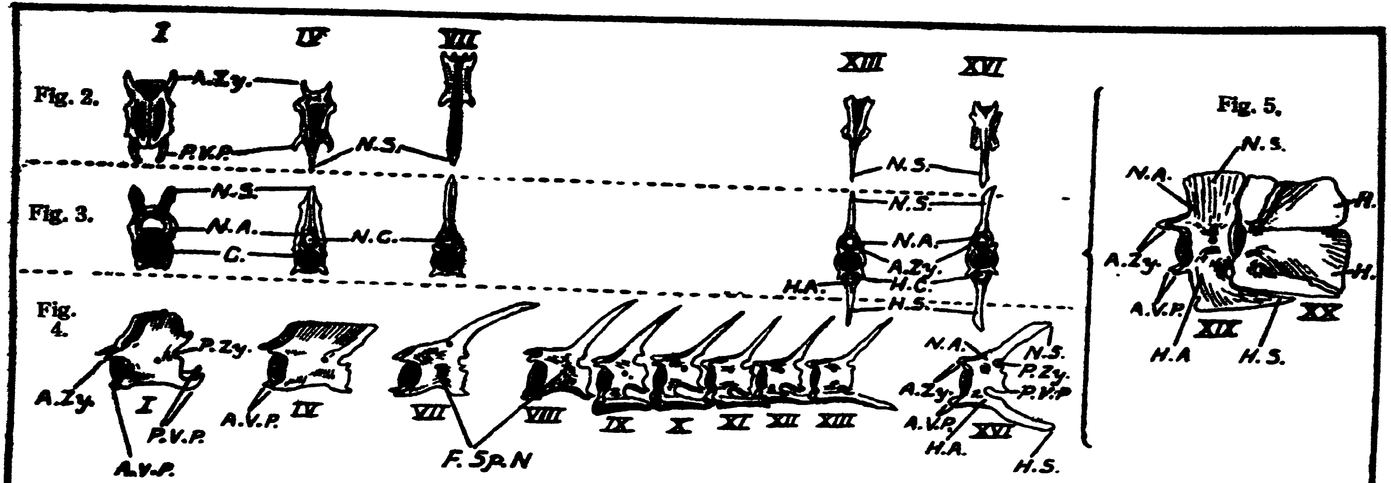

Fig. 2. Dorsal view of vertebae. I, IV, VII, XIII and XVI; Showing incomplete neural arch in I and boat shaped neural arch in IV.

Fig. 3. Posterior view of vertebrae—the same as in Fig 2.—Showing Spina bifida.

Fig. 4. Lateral view of vertebrae, same as in Fig. 2.

Fig. 5. Lateral view of vertebrae: XIX and XX with Hypural bones.

A.V.P. = Anterior Ventral Process; *A.Zy.* = Prezygapophysis; *C.* = Centrum; *N.A.* = Neural Arch; *N.C.* = Neural Canal; *N.S.* = Neural Spine; *H.A.* = Haemal Arch; *H.C.* = Haemal Canal; *H.S.* = Haemal Spine; *H.* = Hypural; *F.Sp.N.* = Foramen of spinal Nerve *P.V.P.* = Posterior Ventral Process; *P.Zy.* = Posterior Zygapophysis.

the atlas (Fig. 4 A. Zy). This articulation is still more strengthened by the embedding of the occipital spine into the groove described above.

All the vertebrae following the atlas are joined with each other by a ligament and in addition they are articulated with one another by means of two kinds of paired processes called pre- and post-zygapophyses (*A. Zy.* and *P. Zy.*) on one hand and anterior and posterior ventral processes (*A. V. P.* & *P. V. P.*) on the other. The former pair arises respectively from the anterior and posterior margins of the neural arch or near about it on the centrum, while the latter takes its origin from the anterior and posterior ventral portions of the centrum. The pre-zygapophyses project over the posterior portion of the preceding vertebrae and fit into the corresponding depressions or facets of the post-zygapophyses. The pre- and post-zygapophyses are seen to be gradually reduced in size towards the posterior end. The pre-zygapophyses of the atlas as described above fit into the facets of the ex-occipitals. The paired anterior and posterior ventral processes form the additional articulating structures. The posterior ventral processes project below the centrum of the succeeding vertebra and fit into the corresponding facets formed by the anterior ventral processes

(ii) *The Caudal Vertebrae* :—They are twelve in number and possess both neural and haemal arches and spines. The neural spines of the first four or five caudal vertebrae are slender and obliquely elongated. Those of the remaining last vertebrae are shorter and stouter and also flat. Corresponding to the neural arches and spines each caudal vertebra possesses ventral haemal arch which is produced below into the haemal spine directed behind. The haemal canal enclosed by the haemal arches carries the caudal artery and vein.

The broad and well developed haemal arches of the first four caudal vertebrae are produced posteriorly into flat and horizontal haemal spines. Each of the latter is continued behind so as to fit into the mouth of the succeeding haemal arch. In this way a flat surface is formed for the attachment of the radials of the ventral or anal fin (Figs. 1 and 4). The haemal arch and the slender spine of the fifth caudal vertebra (Vertebra XIII) also provides attachment to some of the posterior radials of the same fin. The haemal spines of the succeeding vertebrae except the last two are almost similar to the corresponding neural spines in form and position. The haemal spines of the last two vertebrae are however sharply directed posteriorly and become horizontal (Fig. 5, *H. S.*). They come to lie below the second hypural bone and thereby support the latter. It should be mentioned here that the caudal fin is chiefly supported by two hypurals (Fig. 5 *H.*) in addition to the slight support it receives from the last two haemal spines.

The two hypurals mentioned above as supporting the caudal fin seem to be the modified haemal spines of the reduced urostyle *i. e.* the terminal portion of the vertebral column. It may be inferred that the urostyle consists of two segments or vertebrae fused together. The hypurals are flat and vertical bones having a cavity at their distal end for the radials of the caudal fin.

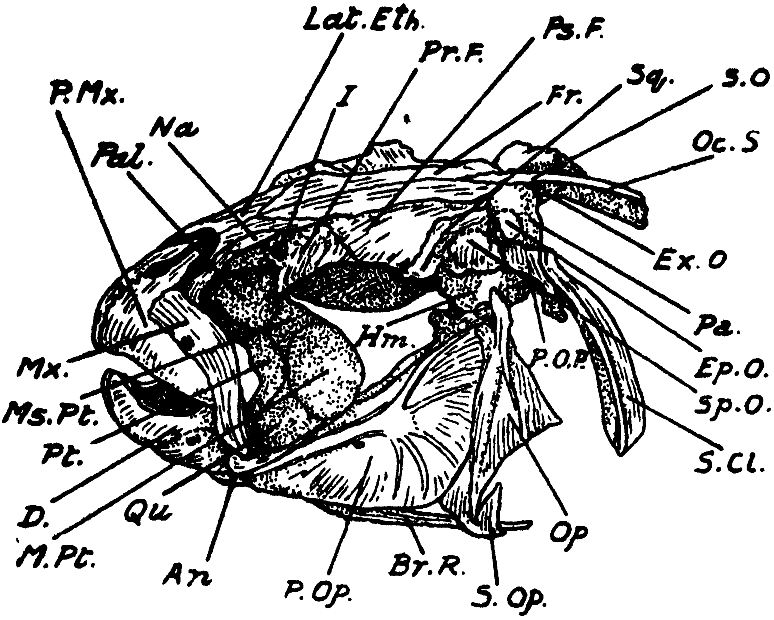

Fig. 6. Side view of the Skull.

An.—Angular; *Br. R.*=Branchiostegal Rays; *D.*=Dentary; *Ep. O.*=Epiotic; *Ex. O.*=Ex-occipital; *Fr.*=Frontal; *Hm*=Hyomandibular; I=Aperture for I Nerve; *Lat. Eth.*=Lateral Ethmoid. *M.Pt*=Meta-pterygoid; *Ms. Pt*=Ento or mesopterygoid; *Mx.*=Maxilla; *Na*=Nasals; *Oc.S*=Occipital Spine; *Op.*=Operculum; *Pa*=Parietal; *Pal*=Palatine; *P.Op.*=Pre-operculum; *P.OP.*=Par-occipital process. *P.Mx* =Premaxilla; *Pr.F.*=Pre-frontal; *Ps.F* =Post-frontal; *Pt.*=Pterygoid or ectopterygoid; *Qu.*= Quadrate: *S.cl.*=Supra-cleithrum; *S O.*=Supra-Occipital; *S.Op* =Sub-operculum; *Sp O.*=Sphenotic; *Sq.*=Squamosal.

All the caudal vertebrae possess small pre- and post-zygapophyses and also the anterior and posterior ventral processes similar to those described in connection with the vertebrae of the trunk region.

(B). *Skull.*—The skull of this fish (Figs. 6, 7, 8, and 9) is slightly depressed in front and a little raised behind. It is of a hyostylic and of tropibasic nature. It is greatly ossified and the presence of a great number of plate-like bones renders it a very complicated structure. It can be divided into two main parts which are already mentioned above.

(i) *The Cranium* :—

Dorso-lateral surface of the Cranium :—At the extreme posterior end of the dorsal surface is situated the Supra-occipital (*S.O.*). It is produced posteriorly into a large blade-like process or occipital spine (*Oc.S.*). The latter extends for some distance in between the groove formed by the bifid neural spines of the first three vertebrae and is embedded there in longitudinal muscles. The supra-occipital sends a wedge shaped process in front which fits in between the two diverging posterior ends of the frontals (*Fr.*). Small irregular Parietals (*Pa.*) are pressed out of the median dorsal line and are found lying one on each side of the supra-occipital. Under each parietal is hidden a thin Epi-otic (Fig. 6 *Ep. O.*) which is one of the bones of the auditory capsule (to be described in connection with the auditory capsule).

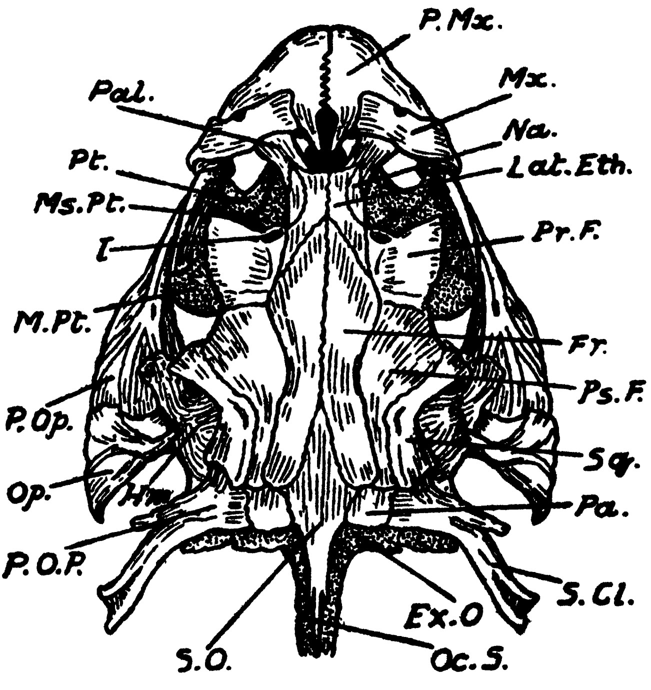

Fig. 7. Dorsal view of the Skull. Letters same as in Fig. 6.

The flat frontals (*Fr.*) are paired bones and are situated immediately in front of the supra-occipital beyond which they meet each other along their inner surface in the median longitudinal line and form practically a single bone on the dorsal surface of the cranium. They are thin and elongated having notches and grooves at both the ends. Anteriorly these frontals overlap the posterior parts of the Lateral Ethmoids (*Lat. Eth.*). Each frontal is connected antero-laterally with the Pre-frontal (*Pr. F.*) and posteriorly it is continued without any suture into the Post-frontal (*Ps. F.*). Both the pre-frontal and post-frontal sink a little below the level of the frontals. The former is articulated by a suture and projects to certain extent over the orbital region. It is perforated by a foramen through which the olfactory nerve goes to the nasal organ (Figs 6, 7 & 9, I.). The post-frontal is on the other hand, a part of the frontal proper and is separated from the latter by a strongly developed ridge quite unlike the pre-frontal. Its anterior end is expanded while it is narrowed at its hind end. It projects over the posterior part of the orbital region.

The remaining dorsal surface of the cranium in front of the frontals is covered over by two pairs of bones developed in connection with the nasal or olfactory capsules. The more prominent of the two are the paired lateral ethmoids (*Lat. Eth.*), which are united in the middle-line. The union between the two lateral ethmoids seems to be almost complete since the suture between the two is obliterated. This combined bone develops a median posterior process which fits into a short corresponding groove formed at the anterior margin of the frontals. It is also produced in front into two lateral horns. Each of the latter is articulated anteriorily with the maxilla (*Mx.*), laterally with the palatine (*Pal.*) and ventrally with the vomer (*Vo.*). The other pair of the bones constitutes the nasals (*Na.*). They are greatly reduced in size and are found overlapping the sides of the lateral ethmoids from which they are distinguished with difficulty. The nasals are narrow and crescent shaped bones.

Posterior End of the Cranium :—The foramen magnum is a large rounded aperture at the posterior end of the cranial cavity and is bounded dorsally and laterally by the paired ex-occipitals (*Ex. O.*) and ventrally by a median basioccipital (*B. O.*).

The Ex-occipitals (*Ex. O.*) form a pair of very irregular triradiate bones which surround almost the whole of the foramen magnum. They are situated just below the level of the supra-occipital and are intimately connected laterally, with the ophisthotics (*Op. O.*), ventrally, with the basioccipital and dorso-laterally, with the epiotics (*Ep. O.*). Each of the ex-occipitals almost meets dorsally its fellow of the other side forming thereby an arch-like structure on the dorsal side. A concave and elongated facet into which fits the corresponding process of the atlas is found on the posterior surface of each of the ex-occipitals which therefore like the supra-occipital contribute towards the articulation of the vertebral column to the skull. Each of them is pierced on its side by two foramina for the exit of the ninth and tenth cranial nerves.

The Par-occipital process (Figs. 6, 7 and 9 *P. O. P.*) is situated on the outer side of the parietal and ex-occipital with which it is connected at its base. It may be divided into the basal and the

(2) The Epi-otic (Fig. 6 *Ep. O.*) is not also seen from outside and is covered over by the parietal. It is like the sphenotic, a thin and round bone with two depressions or pits on the internal free (cranial) surface for the anterior semi-circular canal. It is in contact with the parietal, the supra-occipital, the ex-occipital and the pterotic.

(3) The Pterotic (*Pt. O.*) is found at the inner or proximal part of the temporal process and is more ossified than the two ear bones mentioned above. It has two pits or depressions on its inner (cranial) surface. Into these depressions is lodged a part of the posterior semi-circular canal of the inner ear. The pterotic is connected laterally with the dorsal surface of the hyomandibular. It is bounded by the parietal, ex-occipital, ophisthotic and pro-otic.

(4) The Ophisthotic (*Op. O.*) constitutes the distal or posterior part of the temporal process. It is situated on the ventro-lateral side of the par-occipital process and is connected laterally with the sphenotic, and ex-occipital, and ventrally with the basi-occipital.

(5) The Pro-otic (*Pr. O.*) is the stoutest among the otic bones and is greatly ossified. It is flat and is situated on the ventral side of the cranium. It has two depressions on its inner (cranial) surface for accommodating the horizontal semi-circular canal of the ear. It is perforated by two foramina—one for the exit for the four roots of the trigeminal and facial nerves and the other for a branch of the latter. running towards the posterior side of the skull. This bone is surrounded by the parasphenoid, basi-occipital, sphenotic and pterotic.

(b) *The Optic Capsule*:—The Sclerotic will be described in connection with the eye.

(c) *The Nasal Capsule*:—The bones of the Nasal capsule have already been described above in connection with the cranium. They are paired lateral ethmoids and the nasals and the single ethmoid cartilage found above the vomer and below the lateral ethmoids.

(iii) *The Visceral Skeleton*:—It consists of the following:—

(a) *The palato-pterygoid Bar*:—The Palato-pterygoid bar which is the primary upper jaw forms the supporting apparatus for the secondary jaw bones. It is narrow in front and above but broader below and behind. It consists of the Palatine, the three typical Pterygoids and the Quadrate. The quadrate is united behind with the hyomandibular through the symplectic and a small cartilaginous connective tissue. Thus a rigid arch is formed of the hyomandibular, the symplectic and the palato-pterygo-quadrate and it greatly supports the articulation of the condyle of the quadrate into the facet of the articular of the lower jaw. (A fuller description of the bones forming the Suspensorium is given under a separate heading.)

(1) The Palatine (*Pal.*) forms the anteriormost membrane bone of the palato-quadrate arch. It is a curved irregular bone which

lies internal to and behind the maxilla. It is connected anteriorly with the dorsal margin of the maxilla and gives a process on the dorsal side which runs as far as the nasal and is joined with the side of the lateral ethmoid. Its posterior half is connected with the ecto- and ento-pterygoids. It is also connected with the prefrontal and the vomer.

(2) The Ecto-pterygoid or Pterygoid (*Pt.*) is a crescent-shaped bone with both its ends pointing forward. It lies on the anterior side of the palatoquadrate bar and in between the palatine above and the quadrate below. It is connected with the palatine, the ento-pterygoid and the quadrate. It is serrated along certain parts of its posterior margin.

(3) The Ento- or Meso-pterygoid (*Ms. Pt.*) is a thin and irregular bone, a part of which is seen on the posterior and dorsal border of the palatoquadrate arch. The rest of the bone is surrounded by the palatine, the ecto-pterygoid, the quadrate and the meta-pterygoid. It is also serrated over the whole of its articulating surfaces.

(4) The Meta-pterygoid (*M. Pt.*) is also a thin somewhat rounded bone which is less ossified than the other bones belonging to the palato-quadrate arch. It is slightly attached to the hyomandibular above, the symplectic behind, the quadrate below and the entopterygoid in front and above. ✓

(b) *Suspensorium:*—The following bones form the suspensorial apparatus:—

(1) The Quadrate (*Qu.*) is a stout triangular bone which lies at the ventral region of the *Palatoquadrate* arch. It is narrow in front at the condylar region and expanded behind. It bears on its lower anterior surface a prominent saddle-shaped articulating surface, a condyle, for its articulation with the articular of the lower jaw. It develops on its ventral posterior surface a prominent ridge for the attachment of the inner anterior half of the preoperculum. On the inner and ventral surface the quadrate develops a slight groove into which is fitted the anterior spine-like process of the symplectic. In front and above it articulates with the pterygoid, while the whole posterior surface is in contact with the meta-pterygoid and partially with the ento-pterygoid. The quadrate is thus in contact with the articular, the pre-operculum, the symplectic and the meta-, ento- and ecto-pterygoids.

(2) The Symplectic (*Sy.*) is a small and thin bone. It is pointed in front and expanded behind. Ventrally its pointed anterior end fits in the groove of the quadrate described above. Its dorsal end is connected with the lower end of the hyomandibular by means of a patch of a connective tissue. Internally it is united with the meta-pterygoid and with the pre-operculum.

(3) The Hyomandibular (Hm.) is an irregular shaft of a bone with a head which fits dorsally into the groove found on the lateral surface of the auditory capsule. The groove is formed partly in the pterotic on the one hand and partly on the pro-otic and the sphenotic on the other. The head of the hyomandibular is somewhat triangular and along the free edge, it develops an elongated and flattened ridge which is continued forward into a process lying above the ball and socket joint of the operculum (Fig. 9 Socket and Ball). The elongated shaft of the bone passes downwards and forwards and articulates with the metapterygoid and the symplectic by means of the connective tissue. The inner posterior half of the pre-operculum is closely attached to the outside surface of this elongated shaft of the hyomandibular. The latter is thus connected with the auditory capsule, operculum, pre-operculum, symplectic and meta-pterygoid. It bears a foramen below the socket through which passes the hyomandibular branch of the facial nerve.

(4) The Squamosal (*Sq.*) is a curved club-shaped bone and is situated along the outer and posterior margin of the post-frontal with which it is intimately connected. It is a stout bone with two unequal arms or processes. The anterior of the two is long and narrow and projects over the orbital region, the posterior is short and broad. The latter covers from above the sphenotic of the auditory capsule which is described before. The squamosal is connected with the post-frontal in front, the parietal and the par-occipital process behind and the sphenotic, and hyomandibular on the side.

(C) *The Jaws :—*

(i) *The Upper Jaw :*—The secondary upper jaw is divided into two halves by a mesial suture and each of them is made up of two stout investing bones, pre-maxilla and maxilla. The pre-maxillae of two sides are united in the middle by means of the inter-locking (dovetailing) processes, borne by their median faces.

(1) The Pre-maxilla (*P. Mx.*) which lies anterior to the maxilla forms the entire margin of the mouth. It is a thick curved bone, interlocking with its fellow of the other side in the middle line. It is produced dorsally into a process which runs posteriorly towards the ethmoid region where it is embedded in between the two horns of the lateral ethmoids into a fibrocartilaginous substance. The pre-maxilla is continued downwards and behind and comes to lie over the lower jaw at its posterior angle. Along the dorsal spongy margin of the pre-maxilla runs a prominent ridge, which fits into a corresponding groove on the maxilla along its ventral and inner surface. The pre-maxilla bears a single strong tooth which is cemented on almost the whole of the ventral and inner (free) face of the pre-maxilla.

(2) The Maxilla (*Mx.*) lies immediately above and behind the pre-maxilla and runs almost parallel with it. It is toothless and it never enters the gape of the mouth. It is deeply grooved on its ventral and inner sides, the groove embracing the ridged posterior portion of the pre-maxilla. The maxilla is free ventrally beyond the pre-maxilla, when the former lies over the lower jaw at the junction of the dentary with the pre-maxilla. It bears a foramen on the anterior surface for the exit of the maxillary nerve. It is connected with the pre-maxilla, palatine, lateral ethmoid, vomer and the dentary.

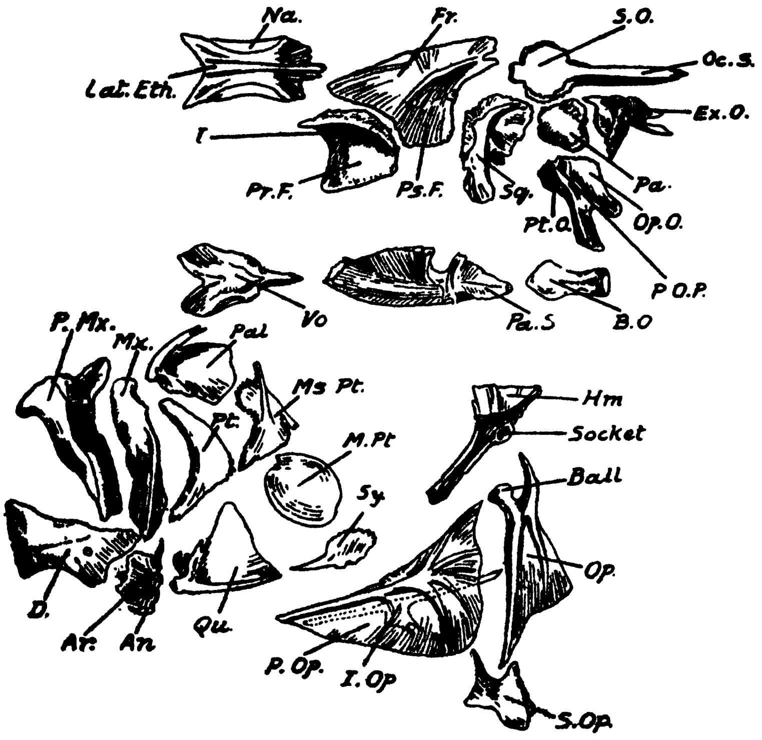

Fig. 9 :—Disarticulated Skull.
Ar.=Articular ; *Sy.*=Symplectic. Remaining Letters same as in Figs. 6 & 8.

(ii) *The Lower Jaw* :—

The lower jaw like the upper is divided into two halves by a similar mesial suture, each half consisting of three bones (6) *viz.*, the Dentary, the Articular and the Angular. The two halves are united in the middle in the region of the dentary by means of the same device described in connection with the pre-maxilla. The dentary forms the ventral margin of the mouth.

(1) The Dentary (*D*) is a very strong and well-ossified bone which forms about two-thirds of each ramus. It is deeply forked behind and the two limbs of the fork enclose a large triangular cavity into which the articular is set. The dentary is comparatively thin and spongy in this particular region and has a foramen at this end for the exit of the mandibular nerve. It bears a single strong tooth, curved and tapering dorsally almost to a point.

(2) The Articular (*Ar.*) is a large spongy bone connected with the quadrate by means of a saddle-shaped glenoid fossa. Most of its anterior portion is fitted into a deep groove in the dentary described above and only its small posterior portion is therefore to be seen from outside. It is connected with the dentary, quadrate and angular.

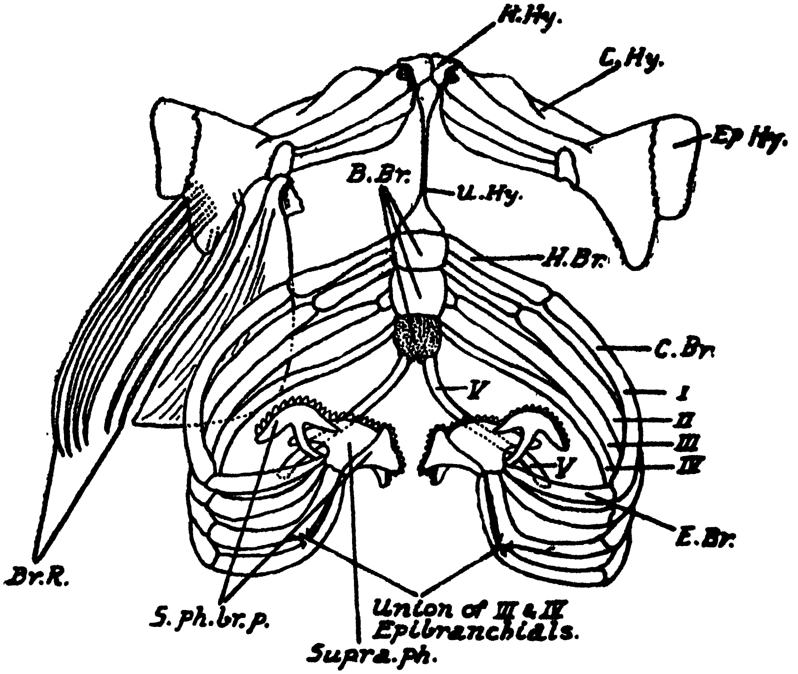

Fig. 10—Dorsal view of the Hyoid and Branchial Arches.
B.Br.=Basi-branchial; *Br.R.*=Branchiostegal Rays; *C.Br.*=Cerato-branchial. *C.Hy.*=Cerato-hyal; *E.Br.*=Epi-branchial; *Ep.Hy.*=Epihyal; *H.Br.*=Hypo-branchial. *H.Hy.*=Hypo-hyal; *S.ph.br.p.*=Superior pharyngo-branchial process. *Supra.ph.*=Supra-pharyngeal Bone; *U.Hy.*=Urohyal *I, II, III, IV* & *V*= Branchial Arches.

(3) The Angular (*An.*) is a small but perfectly distinct bone united to the lower surface of the articular at its posterior end. It is attached to the dentary, articular and with the rod-like interoperculum bone by means of a ligament.

(d) *The Hyoid Arch* :—The Hyoid Arch (Fig. 10) is strongly developed and consists of the following segments :—

(1) The Epihyal (*Ep.Hy.*) is the dorsalmost segment of the hyoid arch. It is a small flat piece of bone, articulating dorsally with the hyomandibular, symplectic and meta-pterygoid through a small cartilage on the inner side of their junction. This small cartilage just mentioned may represent the interhyal. The epihyal is also connected with the wing-like process of the inter-operculum and ventrally with the ceratohyal.

(2) The Ceratohyal (*C.Hy.*) is the stoutest bone of the hyoid arch. It is a well developed elongated and flat bone which provides attachment on its outer margin to about six slender branchiostegal rays and also to a wing-like expanded thin structure. The latter may either be formed by the fusion of certain branchiostegal rays or may consist of a single greatly expanded ray. It is articulated to the inner side of ceratohyal which bears a deep facet for its attachment. The ceratohyal is hollowed into a long tubular canal into which is fitted the hypohyal.

(3) The Hypohyal (*H.Hy.*) is a small piece of bone which is ossified at the centre but is cartilaginous at the circumference. It articulates loosely in the mid-line with its fellow of the other side, and on the outer side with the ceratohyal as described above.

(4) The Urohyal (*U.Hy.*) is a median unpaired bony rod which is expanded at both the ends but is slender in the middle. It is attached by one of the expanded ends with the hypohyal and by the other with anterior portion of the basi-branchial after passing through the sterno-hyoid muscles. This mid portion of the urohyal is narrow and slender.

(5) The Interhyal may be, as described above, a very small cartilaginous piece which is found between the epi- and ceratohyals on one hand and the interoperculum and symplectic on the other.

(e) *The Branchial Arches* :—The branchial arches (Fig. 1) are situated behind the hyoid arch and they are five in number as denoted by Roman numbers in Fig 10. A typical branchial arch is transversely divided into four segments—the Pharyngo-branchial, the Epi-branchial (*E. Br.*) situated dorsally, the Cerato-branchial (*C. Br.*) laterally and the Hypo-branchial (*H. Br.*) ventrally. The hypo-branchials of the two sides are attached to the median unpaired Basi-branchial (*B. Br.*). The first three arches are complete but the fourth and the fifth are greatly modified by fusion or reduction of different segments. The branchial arches are 7 -shaped with the pharyngo and hypo-branchials pointing forward. (6). The segments of the first three arches are grooved on their outer convex side for the reception of the blood vessels and the nerves; while on the inner side they support horny processes called gill rakers. The latter do not seem to form a part of the skeleton but they appear to be the processes of the outer epidermal layer of the pharynx.

The first branchial arch is complete except that its pharyngobranchial is fused with those of the next three arches. The pharyngobranchials of the first four arches are thus fused and give rise to a large irregular flat bone on the dorsal side. It is then called "Supra-pharyngeal bone" (Supra. ph.) It bears teeth on ventral margin which appear to serve as powerful masticating apparatus. The epi-branchials of the first four arches start close together from the outer base of the supra-pharyngeal. The epi-branchial of the first arch gives off in addition a small superior pharyngo-branchial process (*S. ph. br. p.*) from its distal end. It is more or less a T-shaped structure bearing small teeth at the margin and itself pointing towards the anterior side. A similar structure is also found arising from the epi-branchial of the fourth arch. The epi-branchials are succeeded ventro-laterally by long and stout cerato-branchials which are found grooved in the first three branchial arches. The cerato-branchials meet ventrally the hypo-branchials which are connected with the median basi-branchial.

The second and third arches possess also all the parts described above except that the third hypobranchial is very small. The fourth arch is devoid of the hypo-branchial and its long cylindrical cerato-branchial is directly articulated to the side of the posterior cartilaginous segment of the basibranchial. The epi-branchials of the third and the fourth arches are indirectly connected with each other at a particular point through the meeting of short spine-like process of each. The fifth arch is reduced to a single piece. It is the cerato-branchial which is directed behind and outward. Anteriorly it is articulated with the posterior end of the terminal segment of the basi-branchial.

The median unpaired basi-branchial (*B. Br.*) is well developed along mid-ventral line of all the arches. It is made up of three segments out of which two anterior ones are well ossified and the last one is cartilaginous. It appears that the three segments represent the five basi-branchials fused together. In front the basi-branchial is attached to the urohyal of the hyoid-arch.

(*f*) *The opercular bones*:—The opercular bones (Figs. 6, 7, 8 and 9) are the following:—

(1) The Operculum (*Op.*) is a slightly striated and strongly ridged bone which is dorsally articulated to the external surface of the head of the hyomandibular by a ball and socket joint (Fig. 9). It gives a prominent curved process just behind its articulation overhanging the joint. The operculum is drawn out ventrally into a spine-like process going over the suboperculum. It is connected somewhere near its mid-region with the posterior end of the inter-operculum by means of a ligament.

(2) The Sub-operculum (*S. op.*) is a thin leaf-like bone and the smallest of the opercular bones. Dorsally it gives off two processes between which the spine of the operculum is inserted.

(3) The Pre-operculum (P. Op.) is the stoutest and the largest of the opercular bones. It lies anterior to the operculum. It has several calcified radiating ridges and is somewhat D-shaped. It is situated on the outer margin of the hyomandibular, symplectic and quadrate and completely covers the rod-like interoperculum.

(4) The Inter-operculum (I. Op.) is a rod-like elongated bone and bears a ventral wing-like expansion near its mid-region. It extends from the middle of the operculum to the angular (of the lower jaw), to which it is attached by a ligament. It is entirely hidden from view by the pre-operculum to which it gives a sort of support from within. In this fish it is not connected with the sub-operculum. It is also attached by a ligament to the outer surface of the hyoid so that the gill covers cannot open or shut without the hyoid apparatus executing a corresponding movement.

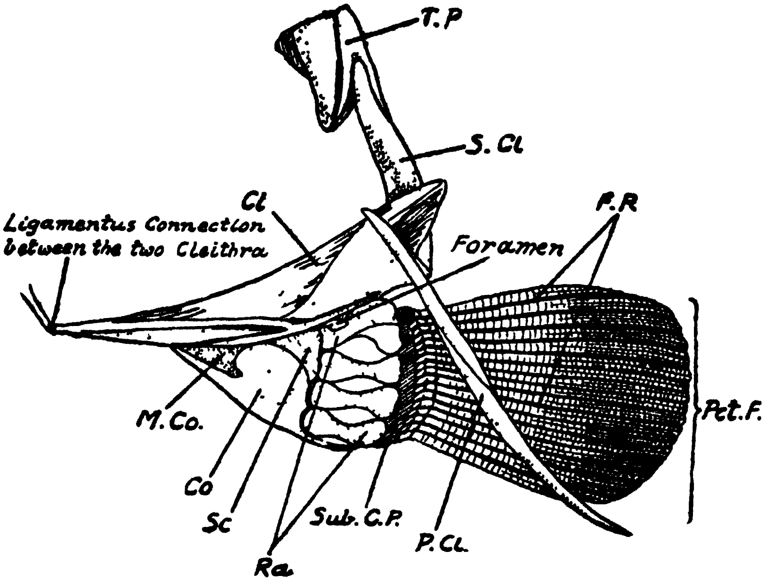

Fig. 11 :—Ventral view of the left half of the Pectoral Girdle and Fin.
Cl.=Cleithrum; *Co.*=Coracoid; *F. R.*=Fin-rays.
M. Co.=Meso-coracoid; *P. Cl.*=Post-cleithrum.
Pct. F.=Pectoral *Fin*; *Ra.*=Radial; *S. Cl.*=Supra-cleithrum.
Sc.=Scapula; Sub. *C. P.*=Sub-Cartilaginous Pad.
T. P=Temporal Process.

II. THE APPENDICULAR SKELETON :—

(A) *The Pectoral Girdle* :—The pectoral girdle (Fig. 11) of this fish is a greatly ossified structure which consists of Cleithrum, Supra-cleithrum, Post-cleithrum, Scapula and Coracoid. The first three are membrane bones and the last two are cartilaginous bones. The girdle is however mainly supported by these three investing bones since the two replacing bones are greatly reduced. The investing bones are articulated with one another and with the forked temporal process of the skull in such a manner that the girdle acquires the characteristic hoop-like shape. The pectoral girdle of each side is united through a ligament with its fellow in the ventral region, at the extreme distal end of the cleithrum. The latter attains a great development and the post-cleithrum is prolonged backward and inmard to be deeply imbedded in the body-wall.

(1) The Cleithrum (*Cl.*) or the Clavicle of some authors, is the largest investing bone in the pectoral girdle. It is curved and flattened dorsally and pointed ventrally. The pointed end is connected in the mid-ventral line with its fellow of the other side, by means of a ligament. The dorsal laminated portion gives attachment to the supra-cleithrum externally and to post-cleithrum internally. It is an irregularly ridged and somewhat flat bone and forms the chief support for the pectoral fin since the scapula and coracoid are greatly reduced. The scapula and coracoid are attached to the base of the strongly developed ridge on the inner side of the cleithrum at about its mid-region.

(2) The Supra-cleithrum (*S. Cl.*) or the Supraclavicle of some authors, is a stout, thick and grooved bone. It is connected dorsally by means of a ball and socket device with the apex of a strong forked bone, the post-temporal process of the skull and ventrally with the external surface of the flattened dorsal lamina of the cleithrum. The pectoral girdle is thus attached indirectly to the auditory region of the skull through the supra-cleithrum and the post-temporal process.

(3) The Post-Cleithrum (*P. Cl.*) or the Post-Clavicle of some authors, is a long slender and curved bone, more or less tapering at both ends. It seems to be divided into two segments near about its mid-region. In front it is attached to the cleithrum and behind it is deeply embedded in the body-wall. It is slightly flattened at its junction with the cleithrum but it becomes cylindrical and pointed at its distal end.

(4) The Scapula (*Sc.*) is a thin, irregular and greatly reduced replacing element of the pectoral girdle. It is situated at the base of the fin, dorsal to the coracoid and is attached to the cleithrum near its mid-region. It bears the scapular foramen near its attachment to the cleithrum at its dorsal end.

(5) The Coracoid (*Co.*) is also a replacing bone but it is somewhat more ossified than the scapula. It is irregularly triangular in shape. In front it is attached to the cleithrum immediately below the

scapula. Thus the distal margins of the scapula and coracoid give attachment to the radials of the pectoral fin.

(6) The Meso-coracoid (*M.Co.*) is perhaps represented by a small portion of the cartilaginous area in front of the coracoid.

(B) *The Fins* :—

(a) *The Pectoral Fin* :—The Pectoral fin (Fig. 11) is thin and well-expanded. It is supported by the endoskeletal radials and dermal fin-rays. It has no axis and hence the radials articulate directly on to the scapulocoracoid region of the pectoral girdle. The radials (*Ra.*) or the basal elements are reduced to only five in number and are very short. They, therefore, scarcely project beyond the body-wall and the whole of the visible portion of the web of the fin is always supported by the dermal fin-rays called the " Lepidotrichia". The radials which are like an hour-glass in shape, are arranged in a single row.

There are about seventeen fin-rays (*F. R.*) which are really double in nature though they appear to be single from outside. They are united laterally with one another by a connective tissue and also along their backs from the margin inward over a greater length. Each apparently single ray can easily be demonstrated as to its double nature since it can be separated out into two really single rays. The union between the two corresponding elements extends from the margin inward almost to the basal end where the two single rays separate out to form a small fork. The two limbs of the fork thus formed embrace between them a sub-cartilaginous pad (*Sub-C. P.*). The latter is found between the distal ends of the radials and proximal ends of the fin-rays. Each fin-ray is thickened and transversally segmented over a great part of its length, and bifurcated and frayed distally. The whole fin is covered over by spineless smooth skin.

It may be mentioned in this connection that the pelvic girdle and also the pelvic fins are absent.

(b) *The Dorsal Fin* :—The single dorsal fin (Fig. 1. *D. F.*) is supported by the soft dermal finrays and the endo-dermal radial elements. The latter almost sink into the muscles of the body and are situated at the base of the fin while the former contribute to the formation of the main skeletal frame of the visible portion of the fin.

There are thirteen radials (*Ra.*) and each of them is bi-segmented consisting of a proximal (axomost) and a distal (baseost) segment. The proximal or axomost segments of all of them are elongated and rod-like in structure. They are interposed between the subjacent corresponding neural spines, to which they are firmly attached. All of them except the first are situated between the neural spines of the vertebrae from seven to thirteen. The first on the other hand lies outside and above the neural spine of the seventh vertebra. The arrangement of interposition of the radials in between the spines is that the two radials following the first in singles, next four in twos and the last six in threes, are found between the two adjacent neural spines. The distal extremities of the proximal segments fuse together into a continuous peripheral margin which is loosely connected with the distal cartilaginous segments by means of a narrow intervening strip of fibrous tissue. The distal segments corresponding exactly with the proximal segments in number are simple, cubical and cartilaginous nodules. They are firmly clasped between the two limbs of the fork of the proximal ends of the dermal fin-rays.

The fin-rays or lepidotrichia agree in number with the radial elements and are transversally segmented and branched distally. They are proximally rather thick and round like a rod but distally they are thinner, flattened and branched. They are arranged like the fin-rays of the pectoral fin as described above. (3 & 7).

(c) *The ventral Fin* :—The ventral fin (Fig. 1 *V. F.*) is almost like the dorsal fin in shape and size and is situated opposite the dorsal fin on the ventral side behind the anus. The structure of the fin-rays and their skeletal supports are similar to what has been observed in the dorsal fin except the fact that the fin-rays are more numerous than the radials. The haemal arches and spines of the vertebrae from nine to thirteen are broad and horizontal. They fit into each other in such a way as to form a flat basal surface on to which the proximal segments of the radials of this fin are firmly attached. The proximal segments of the radials are nine in number and the first one is the stoutest of them all. The distal segments are, however, twelve in number to which correspond the fin-rays or the lepidotrichia. The paired lepidotrichia like those of the dorsal fin fork proximally for clasping the distal segmental radials between the two limbs of the fork. The proximal and distal segments of the radials are united by the intervening fibrous tissue.

(d) *The Caudal Fin* :—The caudal fin (Fig 1. *C. F.*) appears to be apparently symmetrical to the external view but it is homocercal and not diphycercal. It is further divided into upper and lower lobes which are almost nearly equal. The web of the fin is supported by about thirteen strong fin-rays, out of which six support the dorsal lobe and seven the ventral lobe. Except about two most dorsal and about two to three most ventral, all other fin-rays are flattened and profusely branched distally. In other respect they resemble the fin rays of the other fins. The proximal ends of the fin-rays of each lobe are forked for embracing the distal extremities of the hypural bones (12).

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THE REPRODUCTIVE SYSTEM AND THE SEGMENTAL ORGANS IN THALASSEMA Bombayansis (Prasad & Awati)

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In Thalassema bombayensis, the sexes are separate but they cannot be distinguished by their external appearance except during the breeding season, when the male seems to be more reddish with a distinct shade of a shining pink colour, while the female has a dull dark red appearance.

The breeding season lasts from June to November and during this period animals are found with their segmental organs fully packed with sexual cells, either sperms or ova as the case may be. In numbers the two sexes are approximately equal.

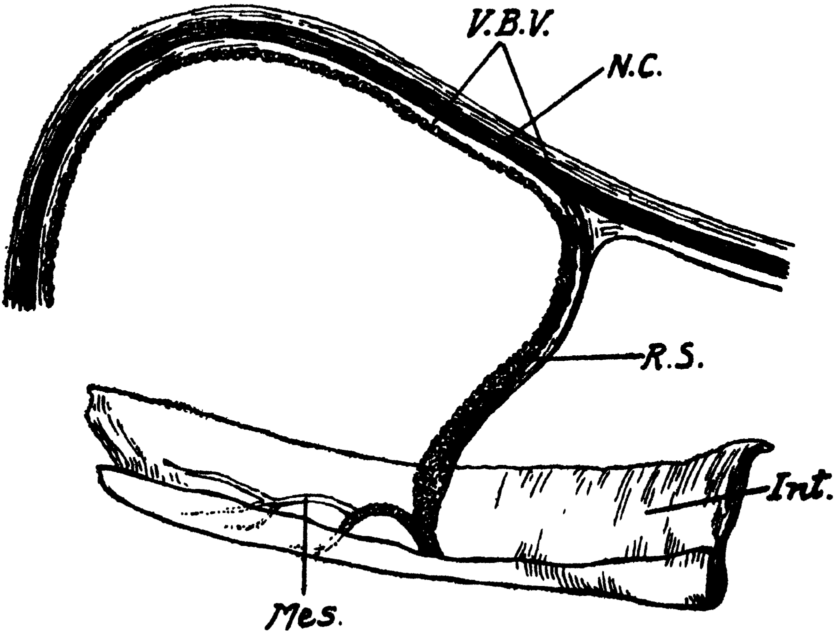

Fig 1. Showing the place of the reproductive organ and its extent × 80.
Int=Intestine ; *Mes.*=Mesentery ; *N. C.*=Nerve Cord ;
R. S.=Reproductive Stolon ; *V. B. V.*=Ventral Blood Vessel.

The Reproductive organ or Genital Stolon or Rachis. There is a single gonad found attached to the posteriormost part of the ventral vessel as the latter leaves off the nerve cord for its attachment to the ventral side of the post-collateral intestine in front of the opening of the anal vesicles into the rectum. The reproductive organ is attached not only to this floating part of the blood vessel but is also seen extending anteriorly on the dorsal side of this vessel when the latter is still attached to the nerve cord (Fig. 1).

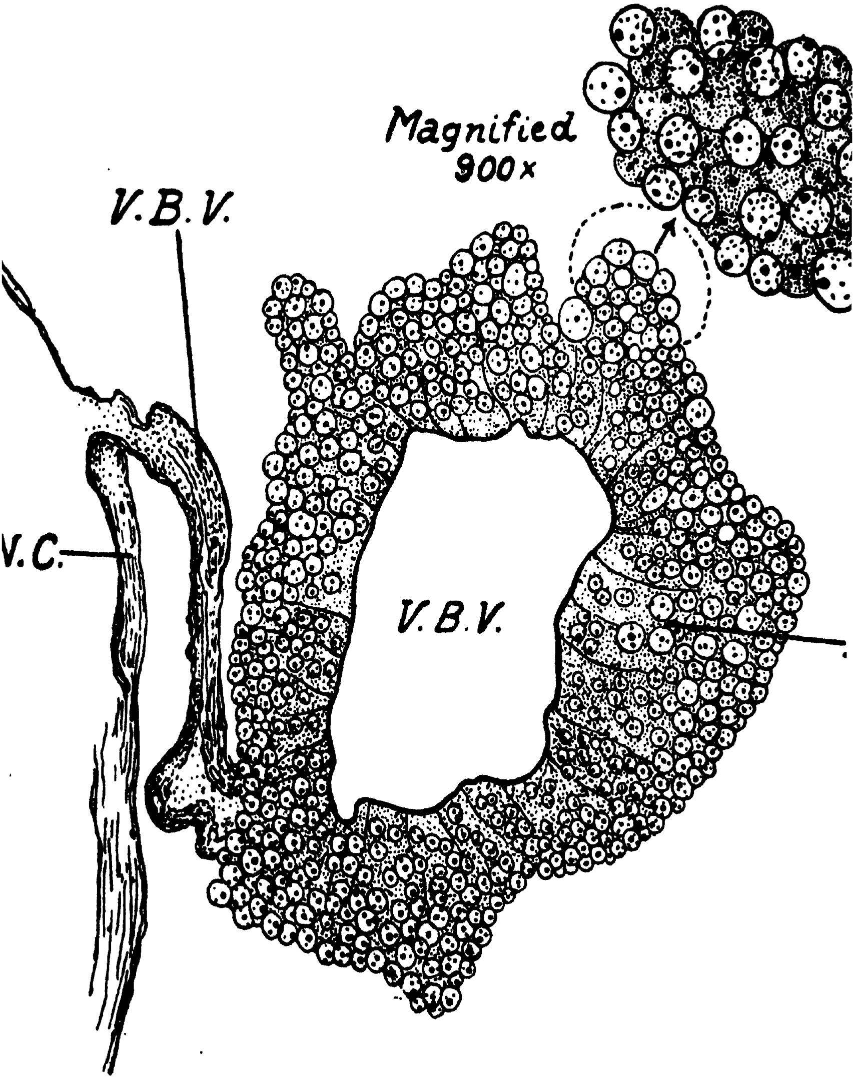

Fig. 2. .Transverse Section of the genital Stolon. × 400. *N. C.*=Nerve Cord; *S. C.*=Sexual *V. B. V.*=Ventral blood Vessel.

The gonad just described may be called the Genital Stolon. The sexual cells are found developing in this genital stolon. They are more or less similar in appearance in the beginning of their development in both the sexes. The masses of these cells appear like small bunches of miniature grapes (Fig. 2). After a time they become detached from the genital stolon, drop into the body cavity and float in the coelomic fluid where their further development takes place.

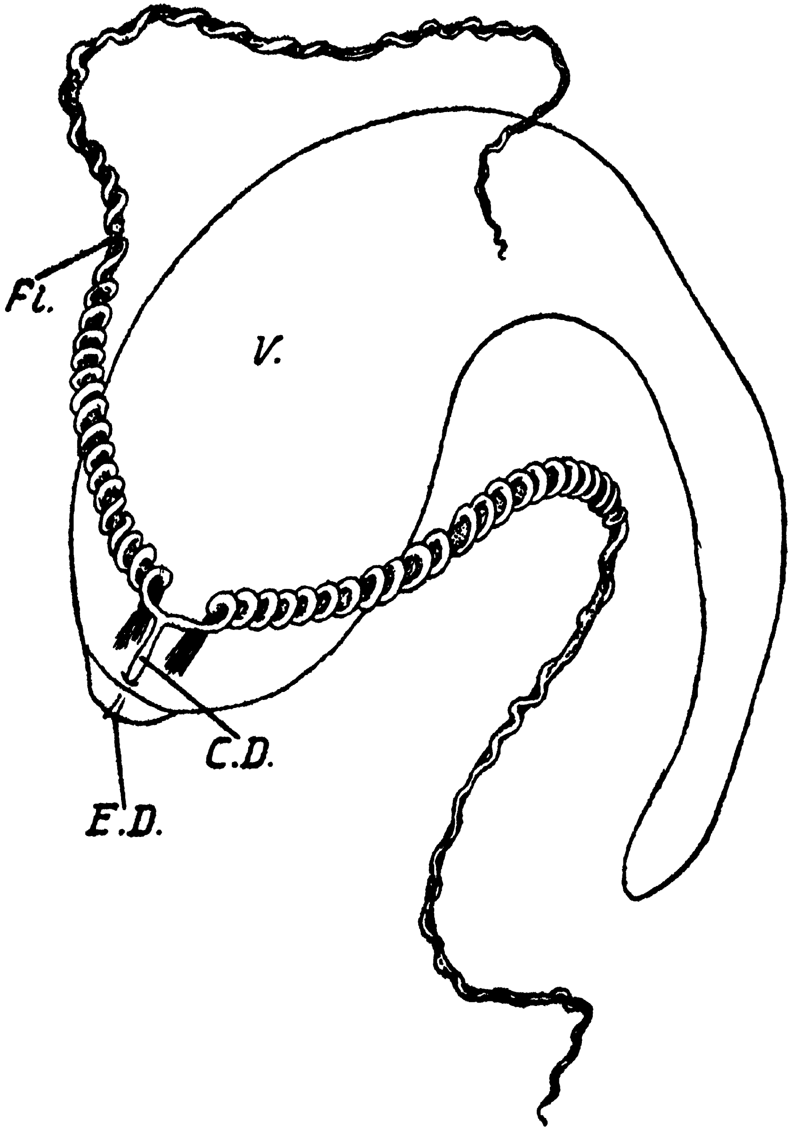

Fig. 3. Segmental organ. × 40
C. D.=Common Duct ; *E. D.*=Efferent Duct ; *Fl.*=Flagellum ; *V.*=Vesicle.

When floating in the body cavity or sometimes even earlier when attached to the genital stolon, these masses of cells can be differentiated under a microscope either into sperm cells or egg-cells ; the sperm cells consisting of small morulae with numerous minute flagella projecting out all along the circumference. The masses of eggs, on the other hand, show one bigger cell in the centre of each mass and small nucleated cells, probably sister ova, on the periphery. It seems probable that the central cell is the developing ovum growing at the expense of the sister ova.

In the body fluid the further stages are developed until individual sperms or eggs are formed and are found floating in that fluid.

Segmental Organs or Gonoducts. There are four to five pairs of these segmental organs found located in the anterior region of the body cavity on both the sides of the nerve cord. They can be divided into two groups ; pre-setal and post-setal. The former consists of two pairs while the latter two to three pairs. They are equidistant from each other.

Each segmental organ consists of a vesicle with two spiral whip-like structures called flagella, attached by their basal ends to ventro-lateral sides of the vesicle but free distally and floating in the body fluid. Each vesicle is attached by its proximal end to the ventral wall of the body cavity while it is projected into the latter at its distal end. Into the cavity of this vesicle opens a narrow duct formed by the flagella and from the same cavity a shorter efferent duct opens to the out side through the epidermis by a minute aperture. (Fig. 3.)

The size of the vesicle and also of its cavity seems to vary according to the state of maturity of the animal. In an unripe animal the vesicle is shrunk to a very small size and its cavity is completely reduced. But in mature specimens, on the other hand, there is a great increase in size in both of them. Each vesicle is elongated and blown out with a capacious cavity like an inverted toy balloon. In this condition it shows diverse shapes. In some specimens the proximal part of each vesicle is blown out, while the distal portion is compact and tapering ; in others it presents a beaded appearance, *i. e.* successive blown out portions separated from each other by constrictions. In still others the vesicle assumes the shape described in the beginning. All these different shapes are probably due to different degrees of inflation of these vesicles on account of the storing of sexual cells within them. (Fig. 4).

These vesicles also show colour variations when they are distended with sexual cells. In the female they have a dull translucent appearance owing to the presence of eggs within them, while in the male on the other hand, they are whitish on account of a milky appearance of sperm masses. These vesicles can then be seen to a slight extent

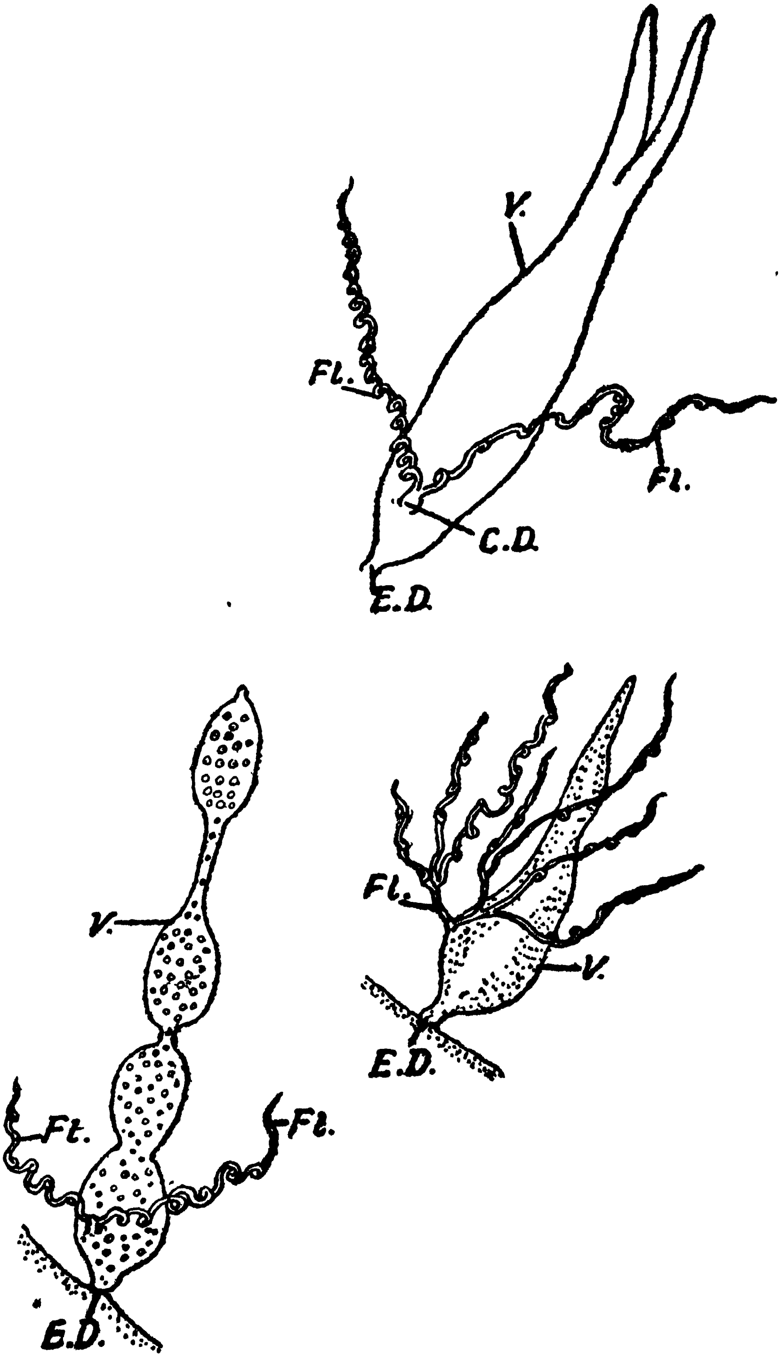

Fig 4. Showing variations in shape and branching in the segmental organ, (diagrammatic) N. B. Lettering same as Fig. 3.

from outside without dissecting the animal, through more or less transparent body wall. The dimorphic colours of the sexes mentioned above, may be due to this fact.

The whip-like structures or flagella as mentioned above are paired structures and are found attached to the basal portion of each vesicle. They are spirally twisted and have cilia all along their outer margins. They are generally broader at the base and taper towards their free ends. The distal portions of these flagellae are found floating in the body fluid and they show certain amount of wriggling movements. (Fig. 3).

These paired flagella unite with each other just before they become attached to the vesicle. After the union a common duct is formed by them which runs along the base of the vesicle till it opens into the cavity of the latter.

In an unripe specimen these flagella are smaller and shorter with closely compact spirals but they become elongated and their spirals are greatly drawn out in the breeding season. In this condition they are able to cover longer distances round about the vesicle to which they are attached.

These segmental organs of Thalassema bombayensis show certain variations with regard to their numbers and the branching of the same and the flagella. In the majority of specimens investigated, four pairs of these organs have been found but in one or two specimens five pairs of the same organs have been observed. In a certain specimen the tip of the vesicle of one of the segmental organ has been found bifurcated. Some of the flagella have also been found branched in some specimens and these branches are occasionally found sub-dividing. In this way the number of the flagella is increased. All these flagella unite together to form the common duct before they are attached to the vesicle. (Fig. 4)

In its fully extended form the vesicle, when seen in a section under a microscope, shows three distinct layers of tissues. The innermost layer lining the cavity consists of an epithelium the cells of which are more or less cubical with nuclei in the centre. No cilia are to be seen in this region. The middle layer is formed of muscles either circular, longitudinal or oblique (very difficult to make out), while the outermost layer is formed by the peritoneal layer which consists of flat cells with nuclei (fig. 5).

The histological structure of the flagella in Thalassema has not been so far described by any previous writer. In Echiurus, Umbleton (2) mentions them as solid organs.

Each flagellum, when examined in a series of sections, consists of four distinct parts: they are (1) the body of the flagellum, consisting of a compact tissue of longitudinal and oblique muscles with loose connective tissue fibres in between them ; (2) the groove or gutter, which is a deep open groove situated on one of the sides of the body. It is lined with ciliated cells which are more or less cubical in shape and have nuclei in the centre ; (3) the lips of the groove, which are flat and extended out on both the sides of the groove. The epithelium of the lips is also ciliated like that of the groove ; and (4) the vacuoles.

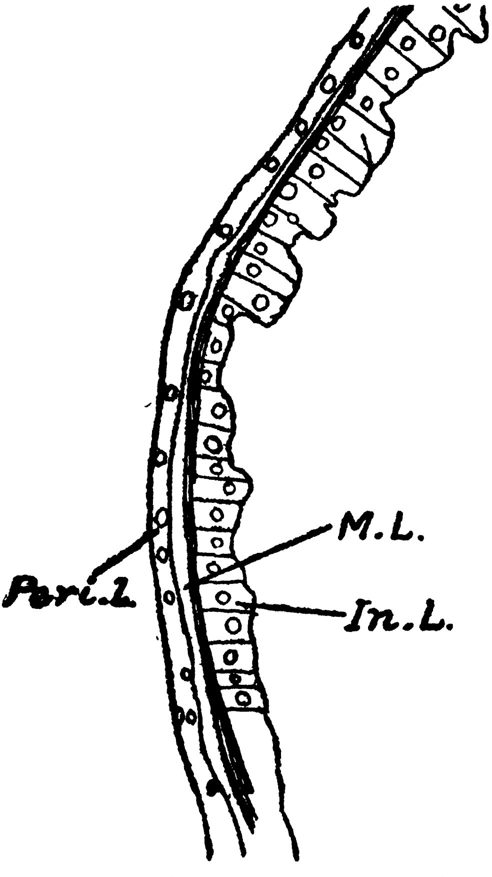

Fig. 5 Showing histological structure of a Vesicle. x 80
In. L.=Inner Layer ; *M. L.*=Middle Layer ;
Peri. L.=Peritoneal Layer.

There are two vacuoles one on each side of the groove beneath each lip. (Fig. 6).

The two flagella of each segmental organ are, as mentioned above, separate from each other and the vesicle for a greater length but they approach each other as they proceed towards the base of the vesicle. They then meet each other and form a single structure surrounded by a single wide spiral. The grooves of both the flagella open at this point into each other to form a closed common duct which is wider at first but soon narrows to a smaller tube (Fig. 7).

The latter is then attached to the base of the vesicle. It runs along the ventral side of the vesicle until it opens into the cavity of the latter. Both the parts of the common duct have an epithelium of ciliated cells of a cubical shape with prominent nuclei in the centre. (Fig 8.)

Quite close to the opening of the flagallar duct into the vesicle, another duct going to the outside is formed. Its mouth is broader but it soon narrows into a smaller tube towards the distal end, the whole duct looking more or less like a funnel. This duct may be called the efferent duct of the vesicle. (Fig. 10).

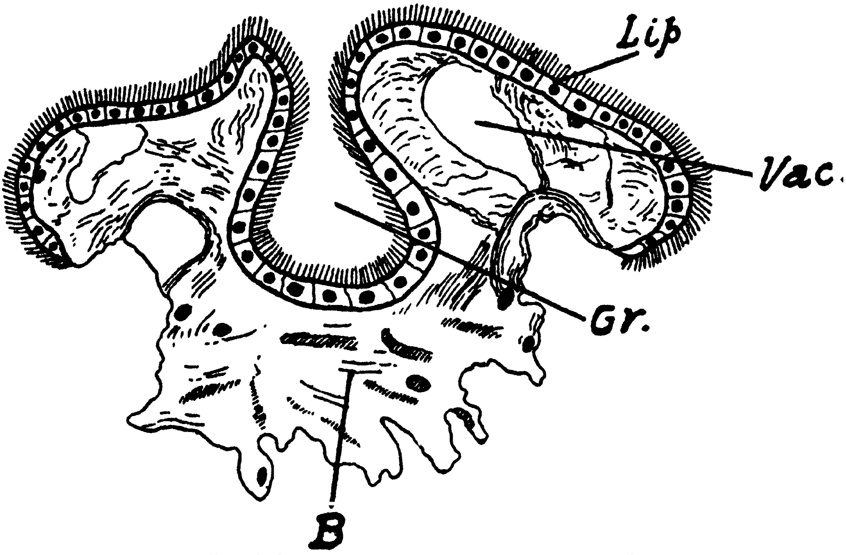

Fig. 6. Transverse Section of a flagellum ×400.
B=Body of the flagellum; *Gr.*=Groove or Gutter;
Lip=Lip of the groove; *Vac.*=Vacuole.

The distal narrow portion of this efferent duct appears to be formed of two parts. The end portion is formed by an invagination of the skin, while the proximal part seems to be the drawn out portion of the vesicle. No ciliated cells are to be found in any part of this efferent duct.

In the breeding season the external openings of the segmental organs are sometimes clearly visible on the ventral body wall lying sunk in pits in a line with the setae.

Function of the Segmental Organs. The vesicles of the segmental organs store eggs or sperms as the case may be till they are ejected to the outside through the efferent duct. These sexual cells are brought into the vesicle from the body cavity by the flagella through

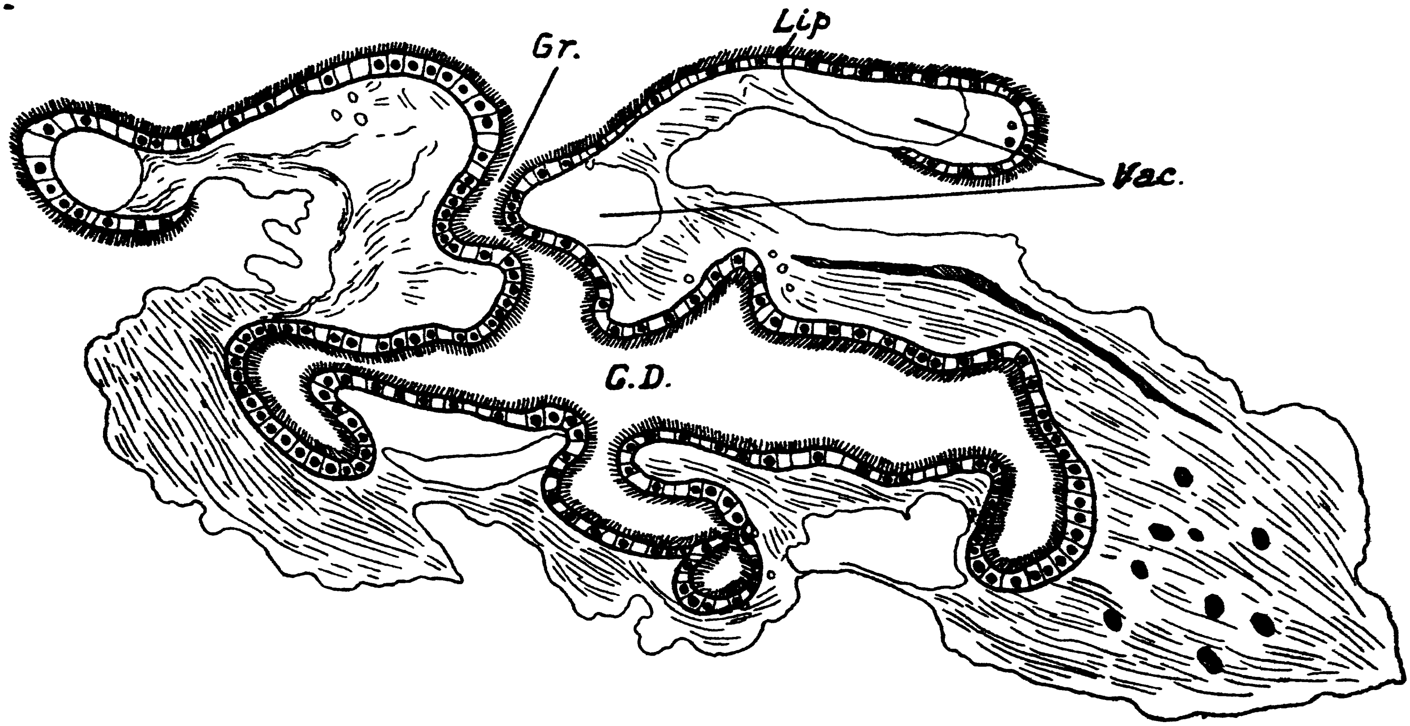

Fig. 7. Transverse of the Common duct. ×400
C. D. = Common Duct; Other letters as in Fig. 6.

their open gutters and the common duct. These segmental organs are therefore acting as gonoducts in these animals. Their homologies will be discussed later.

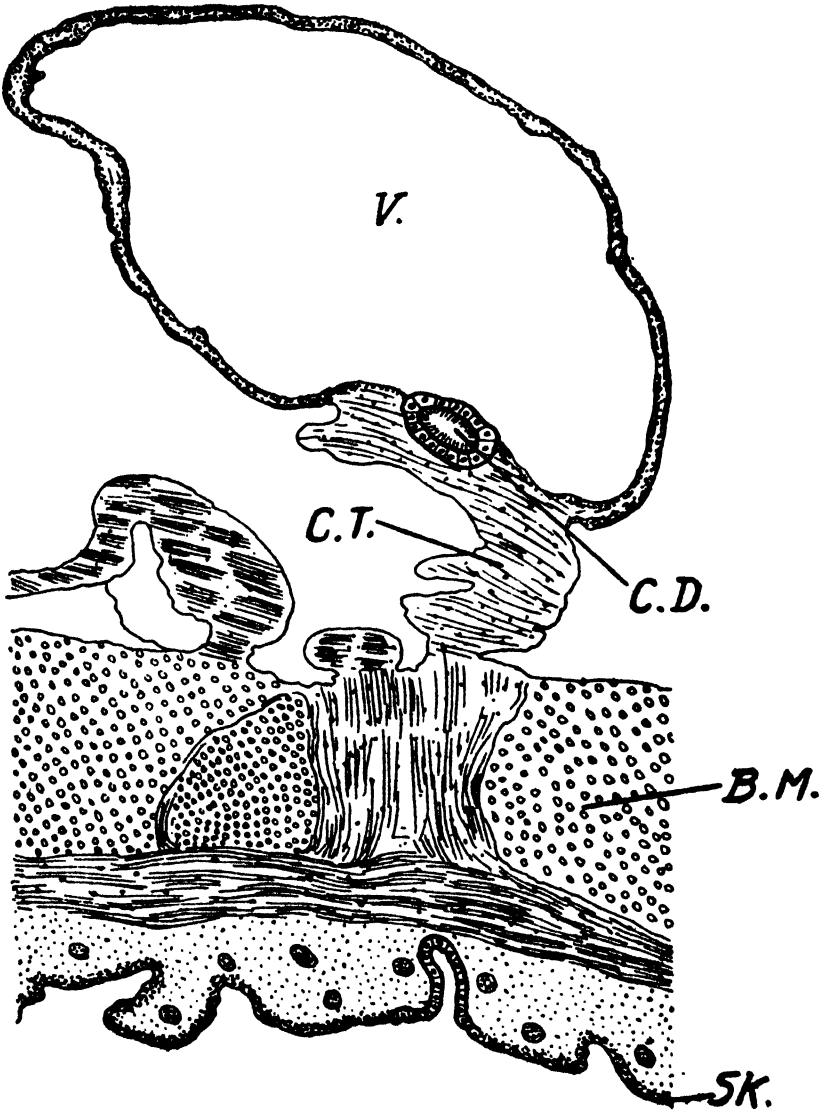

Fig. 8. Transverse section of the Vesicle. × 400.
B. M. = Body Muscles; *C. D.* = Common Duct; *C. T.* = Connective Tissue; *SK.* = Skin; *V.*=Vesicle.

To quote Baltzar (1) "Die Segmentalorgane sind Gonoducte und nehmen denn auch nicht beliebige Zellbestandteile der Zolomflussigkeit, sondern nur fertige Geschlechtszellen auf. Wie diese Auswahl, diese Bevorzugung der Geschlechts-Zellen vor allen anderen Zolomkorperchen zustande kommt, ist ratselhaft." In a series of sections examined for this paper, it has been found that not only sexual cells but coelomic corpuscles also get into the vesicle of the segmental organ. The proportion of the former to the latter is, however, enormous; since the number of eggs or sperms floating in the body fluid is immensely greater than that of the coelomic corpuscles during the breeding season. The coelomic corpuscles are, therefore, very few in the vesicles as compared with sexual cells.

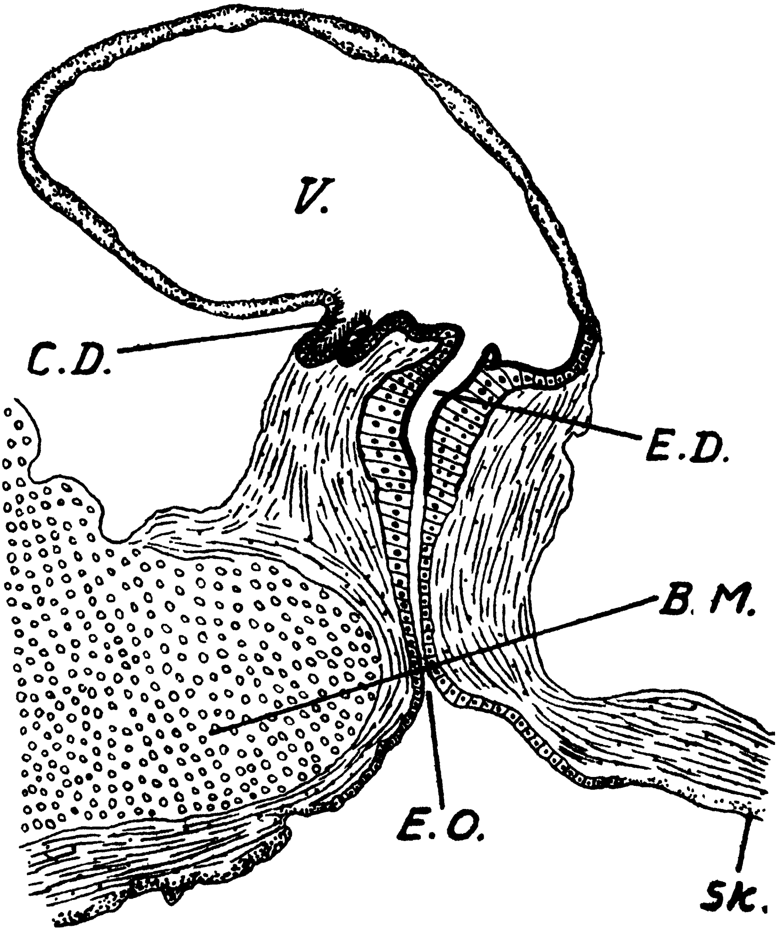

Fig. 9. Transverse Section of the Vesicle. × 400.
E. D.=Efferent Duct ; *E. O.*=External Opening.
Other letters same as in Fig. 8.

" The spiral arrangement of the flagella enables it by lengthening out its spirals to go over longer distances round about the organ. The cilia found on the lips of the gutter produce currents towards the latter and objects taken into the gutter are carried into the common duct and thence into the vesicle by means of the currents produced by the cilia lining these structures. The vacuoles which are found on both the sides of the gutter and under the lips can close or open the mouth of the gutter by increasing or decreasing their dimensions by regulating the flow of blood into them.

During the peristaltic movements of the animal from the posterior to the anterior end, sexual cells are carried with the body fluid to the region of the segmental organs within the range of activity of the flagella. These cells as well as coelomic corpuscles also are brought into contact with the lips and are taken to the gutter by the ciliary currents which are already described above.

The vesicle is distended to its utmost capacity by the packing of these cells. The contents are, afterwards, forced to the outside through the efferent duct, when the vesicle contracts.

These segmental organs seem to be typical coelomoducts similar to those found in other Annelids but they are greatly modified to become gonoducts.

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THE RABBIT OVULATION TEST

By

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Pregnancy is a physiological process, started by the presence of a fertilized ovum, in the body of the mother, which may be implanted in the uterus as in normal gestation, or in the tube, ovary, etc.—ectopic gestation.

It is highly probable that the important manifestations of early pregnancy, usually described as presumptive signs and symptoms are due to the presence in the body of trophoblastic tissue, or its future homologue, the chorionic tissue. This tissue is probably in very close inter-relationship with the anterior lobe of the pituitary body. Novak[1] has shown that the hypertrophy of the pituitary and the presence of pregnancy cells in its anterior lobe continues when a chorion-epithelioma develops in the body, which leads to the supposition that the normal changes in the pituitary during pregnancy are associated with the presence of the chorionic tissue. These changes in the anterior pituitary, probably lead to further changes in the ovary. It is very likely that other endocrine glands beside the pituitary and the ovary play a rôle in the changes associated with gestation.

Chorionic tissue may be present in the form of a tumour and by way of its hormonic influence may mimic some changes associated with pregnancy. Hormonic disturbances may produce one or more of the manifestations of pregnancy—Amenorrhoea, breast changes etc. Thus these facts have an important clinical bearing.

A woman usually realizes her condition when she gets morning sickness, pricking and fullness of the breasts and misses a period. All these changes are manifestations of the presence of chorionic tissue in the body. The cause of the morning sickness is very debated but it is likely that the trophoblastic tissue may have some relation to it.

The relation of the breast changes to chorionic-epithelium is well depicted in the breast activity seen in hydatid moles and in chorionepitheliomata. It is interesting to note that chorionepithelioma in males usually starting in the testis—is often associated with breast changes amounting in some cases to marked gynaecomastia with definite flow of colostrum from the breasts.[2]

In the chain of hormonic influences producing the breast changes, the ovaries also have some share, as it is well known that some ovarian tumours and disturbances of ovarian hormones affect the breasts in a somewhat parallel way.

The amenorrhoea is usually ascribed to the presence of the corpus luteum which is supposed to inhibit ovulation. There is close inter-relationship between the future development of the graffian follicle and the ovum that it has expelled, the mechanism of the inter-relationship being hormonal. If the ovum dies, as it does in most of the cycles in the sexual life of the woman, the follicle does not metamorphose from the corpus luteum of menstruation to the corpus luteum of pregnancy.

If, however, the ovum is fertilized the corpus luteum develops into a corpus luteum of pregnancy and prepares the uterus and the other organs of the body for the pregnancy. It also probably inhibits further ovulation and leads to amenorrhoea.

A woman ceases menstruation in cases of non-uterine or ectopic pregnancy and the bleeding recommences with the death of the ovum, hence the amenorrhœa is hormonic in origin and is dependent on the presence of a live ovum irrespective of its site.

The function of the corpus luteum is soon taken up by chorionic tissue and the corpus luteum is not necessary for the whole period of gestation (according to Frank[25] for 14 days only in the human); this is clearly shown by the increasing number of cases, now on record, in which bilateral oophorectomy during pregnancy did not interfere with the progress of pregnancy.

Further, Cortis[3] has recently drawn attention to the marked softening of the isthmus (Hegar's sign) in his case of chorionepithelioma suggesting that this sign is due to the presence of chorionic tissue.

These different manifestations of early gestation which are probably trophoblastic in origin have been referred to in brief. We shall now proceed to discuss the most important manifestation of the presence of trophoblastic tissue in the human body, *viz.* the presence of some hormone (hypophyseal ? placental ?) in the urine, in demonstrable amounts, which is responsible for the biologic tests of pregnancy. Its presence may be demonstrated by any of the tests mentioned below.

Since the important discovery by Zondek and Aschheim of the diagnosis of pregnancy by biological methods various important contributions have been made in this field. A brief reference will only be made to some of the important contributions before giving a detailed description of the Rabbit Ovulation Test as practised by us. The following modifications have been employed by different workers.

(1) *Siddall's test* (*1928*). The ratio between the weight of the whole animal and the genital tract of the animal, is used as an index. (4,5),

(2) *Aschheim—Zondek's test of pregnancy, 1928.*—(6–15). The changes in the ovaries of immature mice were observed to demonstrate the presence of the hormone in the urine.

(3) *Concentration and detoxification of urine* for the Aschheim-Zondek reaction. In these procedures extraction of the oestrin and the toxic substances by ether and precipitation of the hormone by alcohol is employed. The precipitate is taken up in glucose water and used for the test. By this method the results are obtained in 48–72 hours and the mortality in the animals is greatly reduced. (16–18)

(4) *Brouha modified the test by using male animals.* He utilizes the occurrence of changes in the seminal vesicles and the other male genital organs when immature male mice are injected with the urine of pregnant women. He says that the reaction is always seen naked eye and owing to the comparatively larger size of the animal that can be used, toxicity is less. But the reaction takes a longer time than the Zondek-Aschheim reaction. Dharmendra suggests the descent of the testis in the male rat as a reliable change, in immature animals, for the biologic test of pregnancy. His reported results are, however, too small. (19–22)

(5) *Mazer Hoffman's Test* :—The presence of oestrin in the urine is utilized as a pregnancy test. This test is performed on spayed animals, mice or rats. It is not present as early as the Aschheim-Zondek test. (23, 24).

(6) *Frank* utilizes the *female sex hormone test with blood of the patient.* It is very inaccurate in the diagnosis of early pregnancy and thus not useful. It has, however, a definite importance in the investigation of the endocrine functions in females (25).

THE RABBIT OVULATION TEST.

Friedman[42] has rightly emphasized that this method rests on three fundamental facts.

1. "The ovaries of an isolated female rabbit contain neither corpora lutea nor haemorrhagica, inasmuch as the rabbit does not ovulate spontaneously but only after coitus."
2. The urine of pregnant women contains some substance or substances which simulate in their biologic effects, the secretions liberated by the anterior lobe of the pituitary gland.
3. "The ovary of the rabbit quickly responds to the injection of these substances by the formation of corpora lutea or corpora haemorrhagica."

THE PHYSIOLOGY OF REPRODUCTION AND THE MECHANISM OF OVULATION IN THE RABBIT.

Heape[26] showed, in 1905, that in the rabbit, ovulation is dependent upon copulation, suggesting such a possibility in other animals. Most of the other animals investigated upto now, however, ovulate spontaneously except the cat and the ferret.

M. H. Friedman[27] showed, in 1929, that (1) removal of the whole genital tract with the exception of that portion of the vagina between the neck of the bladder and the external orifice does not prevent ovulation in the rabbit (2) Ovulation may occur in transplanted ovarian tissue. (3) Upto 10 hours after ovulation changes in the discharged follicles of the transplants simulate those seen in the discharged follicles of the normal ovary and concluded :—These results indicate that following coitus there occurs in the humors of the female rabbit some change or changes capable of provoking ovulation, Fee and Parkes [28] (1930) showed that local anaesthesia of the vagina and vulva does not affect (in rabbit does) either the copulation reflex or the occurrence of ovulation after copulation.

ANTERIOR PITUITARY AND OVULATION IN THE RABBIT.

Fee and Parkes [29] (1929) showed that hypophysectomy in the rabbit within one hour after copulation inhibits ovulation which would normally take place 10 to 12 hours later. Hypophysectomy later than one hour after copulation has no such inhibitory effect, although the subsequent development of the corpora lutea appears to be abnormal. Mature follicles which fail to ovulate owing to early hypophysectomy begin to undergo atresia after the normal ovulation time. Inview of the previous work on the relation between the pituitary body and the ovary these effects may be attributed to the removal of the Anterior lobe.

Smith and White [30] performed hypophysectomy, through the oral route and their animals remained in excellent condition and lived longer than Parkes. They found that "ovulation will take place although the pituitary is removed after a postmating period but slightly over an hour in length. In such animals the corpora lutea develop normally for approximately a two day period" (For the effect of hypohysectomy on corpora lutea and on the foetus see Parkes and others [31] and Smith and White).[30]

Hill and Parkes,[32], 1931, described their method of preparation of an anterior Pituitary extract and showed that the acid alcohol extracts of the anterior lobe of ox pituitaries will cause ovulation in rabbits during oestrus, and in pseudopregnant or immature rabbits, hypophysectomized by decerebration. The time taken for induced ovulation to occur in animals during oestrus is rather greater than the normal reaction time after copulation; in pseudopregnant and immature animals, the smallness of the follicles results in a much longer latent period.

From what has been mentioned above, it would be clear that ovulation in the rabbit occurs only after copulation. Further it is a hormonic reaction due to the stimulation of the vulva (and lower part of the vagina) and the anterior pituitary is essential in this chain of hormonic influences.

The gestation period in the rabbit lasts for a month. Thus if a mature rabbit is bought off-hand from a dealer, it would litter within a month if it had been recently crossed. The rabbit comes into heat immediately after parturition and the parturient animal before it has suckled its young ones is the most suitable for assay of ovulation producing substances. If on the other hand the rabbit does not litter at all even after a month's isolation, it can be used for the assay of ovulation producing substances; evidently it has not been crossed recently—thus the ovaries possess mature graffian follicles but no corpora lutea.

It is worth noting that ovulation may be produced by rubbing the vulva and may occur even if a doe is jumped over by another in heat and this ovulation causes a period of pseudopregnancy of about 20 days. Thus every doe should be quite separated in each cage. Some even suggest the possibility of ovulation occurring by psychic effect from the mere presence nearby of a virile male but we have not met with any such experience nor have any workers on the rabbit ovulation test reported such a possibility; as however one only requires female animals for this test one has little opportunity of observing it.

RESPONSE OF THE RABBIT OVARY TO INJECTION OF URINE OF PREGNANT WOMEN

Friedman,[33], [34] in 1929, showed that injection of urine of pregnant women intraperitoneally into non-pregnant rabbits causes the development of numerous corpora lutea which histologically show retained ova with lutein transformation of corpora haemorrhagica. If the rabbits, however, were injected intravenously there resulted within 24 hours a typical corpus luteum with extrusion of the ovum a condition found only in the rabbits post coitum.

According to Jares [35] a single intravenous injection of the untreated urine of a pregnant woman will induce ovulation in a dose of about 3 C. C. or more, ten hours after injection. Larger doses do not hasten the effect and rabbits may be kept constantly provided with corpora lutea by intravenous injection of urine from pregnant women at 10 day intervals.

In their attempt to produce ovulation in hypophysectomized rabbits by the administration of urine extracts, Hill and Parkes [36] experienced great difficulty. In 4 oestrus animals, however, out of 19 one or more follicles ovulated.

In a later communication,[37] they showed that untreated urine of pregnant women causes ovulation readily in the absence of the pituitary body and is thus similar in this particular biological reaction to the substance obtained from the anterior lobe itself. They explain the comparative inefficiency of their urine extracts as due not to lack of the active substance and was probably accounted for by the high concentration of toxic substances characteristic of many of the extracts.

These considerations explain the rationale of the Rabbit Ovulation Test which we have preferred over the other biologic tests on account of the following ADVANTAGES.

The rabbit is a large and tame animal and thus easy to manipulate.

It possesses a well developed ear and the veins in the ear can be utilized for an intravenous injection. Results are brought about in 36–48 hours after the first injection of urine. In the mouse with concentrated extracts results have been observed in 72 hours, but, extraction increases the expense and to a certain extent the time, as in some processes the time required for extraction is some hours.

It is always easy to detect the changes in the ovary of the animal naked eye.

The large size of the animal and its peculiar sex cycle allow it to be used repeatedly for the test, for an ovulation can be produced every 3 weeks or a month.

We shall here describe in brief the TECHNIC followed by us.

The first morning specimen of urine is collected (catheter specimen is not necessary) in a clean, dry vessel, and stored, as soon as possible in an ice chest. It is gently warmed up before injecting. In this country gently rolling the test tube between the palms is sufficient to make the urine warm enough to be injected without causing shock to the animal. If the urine is warmed in a water bath it must be remembered that the hormone is destroyed on heating at 60°C or by prolonged heating at 45°C.

If there is a precipitate it usually disappears whilst warming the urine—if necessary in a water-bath. If the urine does not clear it is usually easy to take up the supernatant fluid from the test tube into the syringe.

Small quantities of urine about 4-6 c. c. at a time are injected at intervals of not less than 2 hours into the marginal ear vein of an isolated mature female rabbit until a total quantity of about 24 c. c. is injected for each test. 48 hours after the first injection an aseptic laparatomy is performed under aether anaesthesia and the abdomen is closed after inspecting the ovaries. If the ovaries show freshly ruptured follicles, haemorrhagic folliclies or corpora lutea, the reaction is positive. If the ovaries show only Graffian follicles which do not show any sign of rupture or haemorrhage, the reaction is negative, whatever be the size of the graffian follicles.

We shall now discuss some of the important items in the method.

AMOUNT OF URINE NECESSARY TO GIVE THE REACTION

The amount advised by various workers varies from 5-24 c.c. (See Table 1). Schoeneck's Table is instructive and we therefore reproduce it here:—

LOW SPECIFIC GRAVITY

Case 39 : 2mo. preg.	2·22.31 :	5	C. C.	Sp.	Gr.	1005	Test	Neg.
	2·28·31 :	17	C. C.	„	„	1001	„	Pos.
Case 48 : 4mo. preg.	2·24·31 :	7	C. C.	„	„	1005	„	Neg.
	2·28·31 :	16	C. C.	„	„	1009	„	Pos.
Case 29 : 2mo. preg.	2·15·31 :	5	C. C.	„	„	?	„	Pos.
Threatened abortion	2·26·31 :	5	C. C.	„	„	1004	„	Neg.
	2·28·31 :	18	C. C.	„	„	1004	„	Pos.

We always inject 18–24 C. C. and from the type of result obtained in some cases of ectopic gestation and abortions, in spite of using the first morning specimen of urine, we consider that smaller amounts would give a false negative reaction.

CHOICE OF THE RABBIT.

According to the literature the rabbit should be 2½ to 3 months old or 1000 to 1800 grams in weight (See Table I).

Snyder and Wislocki found that in immature rabbits prior to the fourth month a single intravenous injection of concentrated urine of pregnancy produces no visible macroscopic change in the ovaries. Beginning with the fourth month a striking change occurs in the ovaries after the injection of

concentrated urine or anterior lobe extract. This response in immature animals is characterized by oedema haemorrhage of the ovaries and production of blood follicles. In the pregnant rabbit, ovulation can be induced throughout pregnancy by the injection of concentrated human urine of pregnancy. There is a tendency towards inhibition of ovulation especially during the first four days of gestation.

Our experience in this matter is summarized in Table II. From this Table it is apparent that animals 2½ months old or more and 1000 gms. or more in weight react to injections of urine. However, from the reaction in case VI G. S. M. C. XCII, (a 3 months old rabbit) which appears to be typical of an immature animal, it seems to us that this animal may not have responded at 2½ months. Every observer must satisfy himself by injecting urine of definitely pregnant cases into immature animals from his particular stock, to determine the earliest age at which his animals respond. If however he has not done this we think he could safely use animals 3 months old or 1100 gms. in weight, in this country.

TIME OF READING THE RESULT.

The earliest time at which definite changes can be detected is variously stated by the different workers; varying from 16-48 hours after the first injection of urine (See Table I).

In discussing this matter it is necessary to know (1) the exact criterion of a positive test. (2) The various stages through which the ruptured graffian follicles and the early corpus luteum pass.

All authors are agreed that ripe graffian follicles of whatever size they may be, do not represent a positive pregnancy reaction.

As mentioned above intravenous injection of urine from a pregnant woman produces in the rabbit, a typical corpus luteum with extrusion of the ovum.

Thus we must determine from the naked eye appearnce of the ovaries whether ovulation has occurred or not. In the ovaries we would expect to find (1) Freshly ruptured graffian follicles and (2) Corpora lutea in various phases of their early development.

When we performed the test by the original Friedman Lapham technic we found that the ovaries invariably contained one or more large haemorrhagic spots. This spot is dark purple in colour and is definitely elevated over the surface of the ovary. (See Plate V-C.) To determine the possibility of an earlier reaction we tried 10 cases with a 30 hours technic—for we had noticed on 5 occasions (see Table III) that it is not possible to get a change in the ovaries in 24 hours and that in spite of the fact that in experiment 6A, a concentrated extract of the urine was used. It was noticed that when the result is read at 30 hours we find freshly ruptured follicles in the ovaries. These definitely show a slight umbilication at their top, site of rupture—and there is usually a slight haemorrhage around it. (see Plate V-b.) Another finding is the presence of very early corpora lutea—earlier than those described with Friedman Lapham technic. These show a definite conical projection over the surface and there is definitely a certain amount of haemorrhage in these, the amount, varying from a little pinkish discolouration to a dark purplish colour in some cases. The appearances of these ovaries are rather variable and not so constant as with the 48 hours technic.

But in all the cases mentioned above, the first morning specimen was used and 18 C. C. were injected. It is possible that if a diluted specimen, as after drinking fluids, is used, the reaction would be less marked. Besides the cases where the result is urgently required are those of ectopic gestation in which there might be a small quantity of the hormone, especially, if the chorionic tissue has been partly destroyed.

Wilson and Corner got encouraging results with a single 5 C. C. injection of urine and laparatomy 16 hours later. But Lapham in the discussion on this paper of Karl Wilson said: "Although Dr. Wilson had very good results with the technic of injecting only 5 C. C. of urine and operating at the end of 12-18 hours, we believe that there are certain to be errors in this technic especially in a case of early pregnancy when there will not be a great quantity of hormone and the rabbit may not react to so small an amount." We must also bear in mind that all rabbits do not ovulate in 12 hours, so that the earliest time when a rabbit could be examined, should be 24 hours after the first injection.

"In emergency two rabbits may be used, one killed at end of 18 hours; if positive, proceed with the treatment of the patient. If negative, the second rabbit may be carried to 48 hours and no time wasted in getting the result."

Reinhart and Scott perform a laparatomy 24 hours after, and in case of doubt (if ripe Graffian follicles only are present) repeat it after 24 hours more giving 5 C. C. more of urine in the meanwhile.

Schoeneck's table of "Clinical Test and Control" is very instructive and we reproduce it here in connection with the present discussion:—

CLINICAL TEST AND CONTROL.

	Number	Error	Correct
5 C. C. 24 hour technic	40	7	83%
5-20 C. C. 24 hour technic	72	9	88%
5-20 C. C. 48 hour technic	11	0	100%
All Technics	123	16	87%

From the experiments of Parkes and Smith quoted above, it is seen that hypophysectomy only in the first hour or hour and a half prevents ovulation. Ovulation occurs at the normal time if the hypophysis is removed after an hour. Thus it is clear that though the hypophysis has already thrown into the circulation a sufficient quantity of the hormone within the first hour of copulation, the ovary does not respond till about 10 hours after coitus, when ovulation occurs. As occurrence of ovulation seems to be the earliest naked eye change that occurs in these ovaries (we do not think Lifvendahl's suggestion of depending on changes in size and colour, is reliable) it stands to reason that under the most favourable circumstances we could expect to get the first changes in the ovaries 10–12 hours after the first injection of urine. Under unfavourable circumstances, as for example, in the case of an animal which is not very sensitive to these injections or of an animal which is in a stage of its sexual cycle when it would not respond very easily, or, when the urine contains less hormone as in very early gestation or when the chorionic tissue is partly destroyed as in ectopic gestation or abortion, the response of the ovaries would necessarily be delayed.

Form this discussion it is clear that the earliest time at which one would expect to get a result, by further improvements, is 12 hours after the 1st injection of urine and at this time the test would be deceptive in a good many cases. Under the present circumstances results may be obtained at 18–30 hours in a certain number of cases, but one should remember that at this stage we do not find the large purple haemorrhagic follicles but freshly ruptured follicles and early corpora lutea. When the test is performed at 48 hours the results are almost 100% correct.

The 30 hour technic cannot be employed as a routine procedure in laboratories, for obvious reasons, because of the awkward hour when the result will have to be read. We therefore advise the routine use of a 24 C. C. 48 hours technic. The technician may perform a few tests at 24 to 30 hours to acquaint himself with the earlier changes in the ovaries. In emergency he may use two rabbits, examining one between 18–30 hours, as required, and leaving the other to 48 hours, if this shows a negative result.

MODE OF DETECTING THE OVARIAN CHANGES.

Schneider and Friedman advised autopsy; Wilson and Corner, Reinhart and Scott, Brouha, and Mettenleiter suggested laparatomy, Priest suggested a preliminary laparatomy, at which both surfaces of each ovary are sketched, indicating any ripening or atretic follicles which may be present. Lifvendahl suggests a preliminary laparatomy and repeated laparatomies at 6 or 12 hour intervals according to urgency.

We used to kill the animal by intravenous injection of air but since the start of the work at the G. S. Medical College we have been successfully performing laparatomies; we use the animal again in 3 or 4 weeks and we have been able to use the animal about six times in some of the cases. A reference to the column of previous laparatomies in the Tables of our results will show how often and at what intervals we have used the animals.

We, however, wonder whether an animal could be operated upon as frequently as Lifvendahl suggests (every few hours); and that with a single injection of such a large amount of urine as 10 C. C. Our experience with the rabbits seems to suggest a high mortality rate with such a procedure. But Lifvendahl goes even further and suggests that the rabbit can be used again in 36 hours if the test is negative. It stands to reason that a procedure which risks the death of the experimental animal during its progress becomes futile if it is employed to shorten the period of the test.

OUR TECHNIC OF LAPARATOMY

As none of the authors have described this in detail, we shall take this opportunity to do so.

Instruments required :—A scalpel, a pair of scissors, preferably with one end sharp and the other blunt, 3 or 4 artery forceps, two dissection forceps, a cutting needle (curved) silk for sutures (No. 4).

The incision in the skin and muscles is preferably made in the middle line and here there are no vessels and one does not meet with any difficulty. In case a second laparatomy is being performed, it is better to go to one side of the original incision, about half an inch away, for if the same scar is incised within 3 or 4 weeks it may bleed much and give trouble. However one has to remember that in the lateral part of the muscles there are fairly large vessels under the skin and the muscle and these should be pushed aside as far as possible. One has however to be always ready with the artery forceps, as lack of attention to this detail may give rise to serious trouble. The lower end of the incision should be at least 1½ to 2″ above the symphisis so as to avoid the bladder even if it is distended.

The ovaries in the rabbit are at a fairly high level and are in contact with the posterior abdominal wall, so that one has to retract the intestines completely by the aid of the index and middle fingers of the left hand introduced inside the abdominal cavity. The thumb and index finger of the right hand then get hold of the ovary and bring it into view. In a positive reaction it is best to avoid touching the ovary lest the large haemorrhagic spots may rupture. The ovary may be gently pulled up by catching hold of the horn of the uterus of that side. Care has to be exerted lest any unnecessary pulling tears the tissues and causes haemorrhage by rupture of the large congested branches of the uterine artery.

After examining the ovaries on either side, the abdomen is closed by suturing two layers by silk as follows, (1) Peritoneum and Muscle (2) skin. When the muscle has been incised, the different layers may retract away at times and it is important to take them all up, from the peritoneum to the most superficial layer (which may retract with the skin) when suturing the muscle. A weak spot may remain in the abdominal wall if the superficial layers are left unsutured ; if the peritoneum is not properly included in the suturing the intestines have a much greater tendency to be adherent to the Anterior abdominal wall.

We pass stay sutures through the skin and cover up the sutured skin with gauze over which the stay sutures are tied. This avoids any scratching of the fresh scar by the animal. The stay sutures are removed in 48–72 hours and the stitches in the skin may be removed on the 6th day. The scar heals up very early and has given trouble only in a very few cases.

RESULTS

From Literature	No. of cases	Error
Friedman (well controlled cases)	92	0
Reinhart and Scott	150	2
White and Severance	44	4
Schneider	200	8
Schoeneck		
5 C. C. 24 hour technic	40	7
5–20 C. C. 24 hour technic	72	9
5–20 C. C. 48 hour technic	11	0
Brouha	190	1
Brindeau and Hinglais	32	0
Schneider	100	2
Brown	22	0
	953	33 (3·46%)

Schoeneck's errors are evidently due to injecting a smaller amount of urine or reading the result earlier.

Schneider attributes his errors to mistake in marking of the rabbit, wrong reading of the macroscopic findings, too early a period of gestation (less than 3 weeks) or to using smaller animals.

Thus it is likely that with a 24 C. C. 48 hour technic the results may prove to be nearly 100 % correct in this test.

For our results see Tables. IV–X

DISCUSSION OF RESULTS.

Biological tests in definitely Non-pregnant Patients.

The test was negative in cases of ovarian and uterine tumours and proved of great value in diagnosis in some cases. It was also negative in cases of ovarian dysfunction and after castration, at least 24 hours later. With 11 C. C. of Serum of a patient 11 days after castration, however, we found a doubtful result, approaching positive. We had specially injected a very large quantity of serum, however, (an amount 3 times the one required for diagnosis of pregnancy). The usual amount would give a definitely negative result.

Case XV illustrates the difficulty in microscopically diagnosing Chorionepithelioma and shows the utility of this test.

CASES OF ECTOPIC GESTATION.

In case 1, which was of 2½ months standing and where no living chorionic tissue was present the negative result can be easily explained.

In case 3, it is quite possible that if more sections were taken, chorionic tissue could have been found somewhere. This case shows that a small amount of living chorionic tissue is enough to give a positive reaction. Where there is not even such a small amount of living tissue the great danger of ectopic gestation—internal haemorrhage—should be over.

We wish to draw the attention of the reader to the fact that in case VI, with 26 C. C. of urine we had only two freshly ruptured follicles on each ovary, and one or two pinkish partially haemorrhagic follicles. We feel confident that smaller amounts of urine and earlier examination of the ovaries would have given a negative result.

In the literature we have been able to find 16 cases where the Rabbit ovulation test was tried, with 8 positive and 8 negative results (Friedman [42] 2 cases both positive, Wilson and Corner [51] 6 cases, 3 positive and 3 negative, White and Severance [10] 4 cases, 2 positive and 2 negative, Soule [58] 4 cases, 3 positive and 1 negative). The negative cases are all described as of old standing.

CASES OF ABORTION—VARIOUS PHASES.

SUMMARY OF OUR RESULTS IN 7 CASES

1	Threatened abortion becoming inevitable	Positive
2	Missed abortion	Negative
3	Missed abortion	Positive, very weak.
4	Death of Foetus 15 days before	Positive
5	Incomplete abortion (Table IX case 5)	Markedly Positive
	a week later.	Negative
6 and 7	Infection after an incomplete abortion clinically resembling ectopic gestation	Positive, very weak.

From this Summary it is clear that even a small amount of living placental tissue in biologic contact with the uterus is sufficient to give a positive reaction. We would emphasize, however, the fact that all our cases have been done with the 24 C. C. 48 hours technic and we consider that smaller amounts and earlier reading would have given negative results in cases like No. 3. The weak positive reaction enabled us to say that this was possibly a case of missed abortion. In this class of cases a positive reaction becoming negative is of great significance and shows that the pregnancy is not going to continue. In advanced gestation, however, it takes several days or even a month or more (see Wilson and Corner [51]) after the death of the foetus, for the test to become negative. This is due to the long time required for the complete destruction of the whole placenta. We have just begun attempting to determine the smallest amount of the first morning sample of urine that would give a positive test and perhaps this may be more helpful than merely a positive or negative result, in diagnosis.

Cases 6 and 7 have proved very instructive to us so far as the clinical aspect of the question is concerned. They clearly show that if there is an infective process in connection with a recent incomplete abortion, it may simulate ectopic gestation in many of its aspects and that the biological reactions may also mislead us.

In the literature there are 38 cases recorded of abortions in various phases performed by the rabbit ovulation test:—

(Wilson and Corner — — — — — — — —31
White and Severance — — — — — — — 4
Schoeneck— — — — — — — — — — — — 3)

In conclusion, we draw the reader's attention, to two contradictory reports, on this subject, in the recent literature.

Bland, First and Roeder [12] say, oestrin disappears from the urine when the foetus dies, as shown by the Mazer Hoffman test. Jeffcoate [15] says, it is increased as shown by a modified Aschheim Zondek reaction.

We may point out however that there is one fallacy in Jeffcoate's work in the fact that he has used intact animals and not spayed ones. Thus it is impossible to exclude an indirect influence on the uterus through the animal's ovaries, stimulated by some substance in the urine injected.

We shall reserve the discussion on the biologic tests in relation to Hydatidiform mole and chorionepithelioma for a future occasion. For the sake of completeness, however, our results are tabulated in table X.

SIGNIFICANCE OF THE BIOLOGICAL TESTS OF PREGNANCY

All the biological tests of pregnancy depend on the presence, in the body, of living chorionic tissue in biologic contact with the blood stream.

Pregnancy is a physiological condition in which Chorionic tissue is present and is in contact with the blood stream ; but should a man or woman be the unfortunate possessor of a tumour containing chorionic tissue *i. e.* a chorionepithelioma they should give a positive biological test. Thus its use in the diagnosis of these tumours both in the female and in the male in the testis for example—is quite apparent.

In normal pregnancy the test is positive as early as 3 weeks after conception. It becomes negative in 2-7 days after puerperium—the rabbit ovulation test becoming negative earlier (48 hours).

As is seen from our cases and from the literature these tests are very useful in diagnosing the presence or absence of pregnancy in clinically difficult cases.

In abnormal pregnancy they are useful in the diagnosis of ectopic gestation, abortions in various phases, and hydatidiform mole.

In ectopic gestation the test remains positive so long as there is a certain amount of living chorionic tissue in biologic contact with the uterus. We found it repeatedly useful and in only one case out of seven was it negative; this case being of long standing with no living chorionic tissue. In such cases, however, the danger of ectopic gestation is much less. We shall, however, emphasise the fact that a full dose of 24 C. C. of urine and a 48 hour interval between the first injection and the laparatomy will go a great way in diminishing the number of negative results.

In cases of death of the ovum in uterine pregnancy, the reaction takes some time to become negative the time being greater in advanced gestation, it may take as much as a month or more. The significance of a positive reaction becoming negative is great in diagnosing death of the ovum.

Though the reaction disappears within 48 hours or a little more, in the normal puerperium, it takes two months or a little more to disappear after the passage of a hydatid mole, though the mole may not be malignant.

In cases of hydatid mole and chorionepithelioma, we have found the test positive with very small amounts (See Table X). We are determining at present the smallest quantity of urine that would give a positive reaction in normal pregnancy. This work, however, will be published in a future paper.

SUMMARY OF OUR RESULTS.

I. Cases of definite Pregnancy.

	Tests	Positive	Error
(a) 24 C. C. 48 hours technic 18 cases 19 tests	19	19	nil
(b) 18 C. C. 30 hours technic	10	10	nil
(c) 3–4½ C. C. Serum read at 25–28 hours	4	4	nil

II. Definitely non-pregnant patients.

	Tests	Negative	Error
14 Cases 15 tests	15	14 1 ?	nil

See Table VII Case 8

III. Cases of ectopic gestation.

Tests	Pos.	Neg.
7	6	1

all corresponded with the Pathological findings.

IV. Various Phases of Abortion: 7 cases 10 tests all corresponded with the Pathological findings.

V. 7 *cases of hydatid mole:* Reaction Positive during the presence of the mole and upto about two months, becoming negative later.

2 *Cases of Chorionepithelioma:* in Case V patient living, Reaction positive 20 days after, negative 2½ months after operation.

In case VII—Positive even in 1/32 C. C. and till death.

After doing a few preliminary tests at the Haffkine Institute by kind permission of the Directors (Major Anderson and later Col. Taylor) this work was started as the Dr. Mangaldas Mehta Research Scholar of the University of Bombay, under Professor V. R. Khanolker, B. Sc., M. D. (Lon.) at the clinical Pathology Department of the Gordhandas Sunderdas College, attached to the King Edward Memorial and the Wadia Maternity Hospitals.

A fair amount of clinical material was secured from the Motlibai and Petit Hospitals.

The cost of the Research is being borne partially by the Gordhandas Sunderdas Medical College and partly by a Grant of Rs. 400/- from the University Research Grants. Our thanks are due to the Heads and the Staff of all these institutions for their kind co-operation and help; our thanks are also due to Dr. J. N. Karande for giving us full co-operation in following two of his cases of vesicular mole.

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TABLE I: *Summary of Technical details on the Rabbit Ovulation Test* (*from the literature*).

	Amount of Urine	Animal (age, weight, etc.).	Time of reading the result (hours after 1st injection).
Schneider 40	5–7 c. c.	16 weeks	30 hours.
Schneider 41	5–7 c. c.	12–14 weeks	24–30 hours.
Friedman 42	3 daily inj. of 4 c. c.	Adult female isolated for a month	48 hours; In urgency 2 animals used; 1st, 18 hours if negative carry 2nd to 48 hours.
Reinhart and Scott . 43	5–15 c. c.; 5 c. c. sufficient in most cases.	Over 3 months	24 hours, if necessary (ripe graffian follicles only) again at 48 hours.
Brouha 44–46	5 c. c.	...	Occasionally within 15 hours; in general 24 hours; exceptionally 48 hours.
Brindeau 47	4 inj. of 5–7 c. c.	...	...
Magath and Randall 48	7–15 c. c.	Over 2½ months	30 hours otherwise the test may be indefinite.
Thales Martins 49	5 c. c.	1–1·5 Kgm.	48 hours; 24 hours in urgency.
Wilson and Corner 50	5 c. c.	4 pounds or over	16 hours.
Davis and Walker 52	Single inj. of 10 c. c.	...	24–36 hours.
Mettenleiter 53	5–15 c. c.	Over 3 months	24 hours.
Schoeneck 56	5–7 c. c. if specific gravity above 1,025; 15 c. c. if specific gravity between 1,015 and 1,025; 20 c. c. if specific gravity below 1,015. Increased amounts injected in 3 or 4 doses.	Minimum requirement 14 weeks & 1,500 gms. Post-partum rabbits or any female animal isolated enough to rule out pregnancy.	Ordinarily 48 hours technic satisfactory and undoubtedly gives most reliable results; when speed is paramout issue 24 hours test offers close to 90% efficiency.
Lifvendahl 57	Single inj. of 10 c. c.	Over 3 months.	Repeated laparatomy 6–12 hourly. Earliest change in the ovary increase in size and change in colour. In 24 hours changes described by others are seen.
K. Stricter 54	Single inj. of 10 c. c.	...	

	Amount of Urine	Animal (age. weight, etc.)	Time of reading the result (hours after 1st injection).
Brown 55	5 c. c. serum, 1 c.c. per 600 to 700 grams. of rabbit weight.	...	24-36 hours.
Ranges of variability.	5-24 c. c.	2½–3 months 1,000-1,800 grams.	16–48 hours.

TABLE II : *Minimum age and weight at which the animal responds.*

Experiment Number	ANIMAL			Amount of urin injected in c.c.	Laparatomy Hrs. after 1st injection	Patient pregnancy of	Finding in the animal's ovaries.
	Serial number	Age in months	Wght. in grms.				
1. G.S.M.C. LXXII	XLVIII	52 days	372	16	52	6 months	The ovaries were very small. Small graffian follicles were seen on the surface of both the ovaries, but there was no ovarian stimulation.
2. G.S.M.C. LXXV	XLIX	2 months	550	25·5	73·5	6 months	Both ovaries thin and narrow. Animal rather toxic from the injections.
3. G.S.M.C. VIII	VIII	2·5	1028	28·5	52	8 months	Both ovaries converted into irregular nodular masses.
4. G.S.M.C. IX	IX	2·5	1398	29·5	52·5	...	Both ovaries showed many haem. Spots.
5. G.S.M.C. XVII	XII	2·5	1173	23	51·25	7 weeks	Left ovary showed 6-7 large haem. follicle Right ovary was practically converted into a reniform swelling due to large haem. follicles at both the poles.
6. G.S.M.C. XCII	XLVIII	3	999	20	54	7 months	Both ovaries converted into nodular haem. masses.
7. G.S.M.C. LVII	XXVI	...	1030	Serum 3 c.c.	26·5	...	3 freshly ruptured follicles on the left and 2 on the right.

Experiment Number	ANIMAL			Amount of urine injected in c.c.	Laparatomy hrs. after 1st injection	Patient pregnancy of	Finding in the animal's ovaries.
	Serial number	Age in month	Wght. in grms.				
8. G.S.M.C. LIII	XXXIX	...	1060	Serum 4 c.c.	25·5	36 weeks	Right ovary showed a nodular haemorrhagic swelling at the upper-pole, and a pinkish enlarged graffian follicle in the middle left ovary showed one haemorrhagic follicle.
9. G.S.M.C. XXXI	XXII	...	1060	Urine 18 c.c.	31	34 weeks	Left ovary showed 3 to 4 pinkish haem. spots. Right ovary showed 3, one freshly ruptured.
10. G.S.M.C. XLIX	XXXIV	...	1072	16 c.c.	46	Incomplete abortion	Right ovary changed into a sort of haem mass. Left ovary changed into a small and more cr less spherical mass.

TABLE III: *Cases showing irreliability of the test when performed with less urine or before 30 hours.*

Experiment Number	ANIMAL			Amount of urine injected in c. c.	Laparatomy hrs. after 1st injection	Patient pregnancy of	REMARKS
	Serial number	Age in months	Weight in grms.				
1. G.S.M.C. III	III	4	...	7	26·5	7 months	Though the graffian follicles were definitely enlarged signs of haem. or rupture were very doubtful.
2. G.S.M.C. IV	IV	4·25	...	24	27·25	5 months	Better marked than case 1, but not so definite as in 48 hours.
3. G.S.M.C. VIA	VI	4	1460	extract prepared from 180c.c.	17	7 months	Reaction negative; when read at 44 hrs. it was markedly Pos.
4. G.S.M.C. XI	III	5	1387	22	24·25 when animal died	Full term	There were 3 enlarged graffian follicles on either ovary but no sign of haem. or rupture.
5. G.S.M.C. XXXVII	XXVII	...	1187	18	12–16	8 months	No ovarian stimulation, when the animal died, 12–16 hrs. after the 1st injection.

TABLE IV.—*Definitely Pregnant Patients—24 c.c. 48 hour Technic—19 Cases All Positive. Early Pregnancy—First Five Months.*

Serial No.	PATIENT.	Experiment No.	ANIMAL.				Substance injected.	INJECTIONS.			LAPARATOMY.			REMARKS.
			Serial No.	Wt. in grms.	Age in months.	Previous Laparatomies.		No.	Amt. at 1 injection in c.c.	Total amount.	Time and date.	Hrs. after 1st injec.	Result	
1	10 days over her period. Aborted a fortnight after performing the test (seen by a doctor).	H11	Isolated mature animal.	...	...	Nil	Ordinary specimen of urine.	6	4—6	32·5	10-20 a.m. 28-10-31	48	Pos.	
2	7 weeks' pregnancy patient being traced.	G17	12	1173	2·5	Nil	Do.	5	4 – 6	23	3-15 p.m. 7-5-32	51·25	Pos.	
3	3 months' pregnancy.	G7	5	1210	4·75	23-3-32 –	Do.	3	5	15	2-15 p.m. 2-4-32	46·25	Pos.	
4	3 months' pregnancy. Referred for a biological test as clinically it was difficult to distinguish it from an ovarian cyst. She later aborted and was seen by a doctor.	G59	29	1352	...	18-7-32+	Do.	4	6	24	2-30 p.m. 13-8-32	49·5	Pos.	As the ovaries showed rather peculiar findings—showing some large unruptured follicles, some flat-topped, partially haemorrhagic follicles, etc., another test was performed, though a positive

														result was declared because of the presence of at least one or two definitely ruptured follicles.
5	Same as Experiment 4	G60	30	1430	...	21-7-32 –	Ordinary specimen of urine.	3	6 – 7	19	2-30 p.m. 18-8-32	48	Pos.	This animal also showed some partially haemorrhagic and some flat-topped follicles.
6	3½ months' pregnancy.	H8	Isolated Mature	...	...	Nil	Catheter specimen	5	4½ – 5	24	10 a.m. 3-10-32	43·5	Pos.	
7	3 months' pregnancy. uterus large–tumour with pregnancy?	G44	29	1435	...	Nil	First morning specimen	3	6	18	4-30 p.m. 18-7-32	51	Pos.	Both ovaries showed irregular nodular masses. Probably hormone content more. Patient could not be traced.
8	Pregnancy 5th months.	H1	Virgin	...	3·5	Nil	Catheter specimen	6	4 – 5	27	9-30 a.m. 16-8-31	48	Pos.	
9	5 months' pregnancy.	H2	Do.	...	4	Nil	Do.	6	4	24	10-30 a.m. 16-8-31	50	Pos.	

Serial No.	PATIENT.	Experiment No.	ANIMAL.				Substance injected.	INJECTIONS.			LAPARATOMY.			REMARKS.
			Serial No.	Wt. in grms.	Age in months.	Previous Laparatomies.		No.	Amt. at 1 injection in c.c.	Total Amount.	Time and date.	Hrs. after 1st injec.	Result	
Advanced Pregnancy—Foetal Heart Heard.														
10	Pregnancy 7th month.	G6B	7	1372	4	Nil	Ordinary specimen	5	5-6	27½	9-30 a.m. 25-3-32	47	Pos.	
11	7 months' pregnancy.	G 13	6	1462	4·75	24-3-32+	Do.	5	5½	27½	3-30 p.m. 21-4-32	53	Pos.	In this case the right ovary had been brought out through an artificial opening made in the rectus muscle, keeping the blood supply of the former intact. It contracted adhesions and showed no corpora hæmorrhagica. The left ovary was changed into a hæmorrhagic mass.

12	7 months' pregnancy.	G14	7	1402	5	25-3-32 +	First morning specimen	4	3 – 5	19	3-30 p.m. 23-4-32	52	Pos.	In this case also the left ovary had been brought out under the skin, but showed no corpora hæmorrhagica, being bound down by adhesions. The right ovary showed two or three hæmorrhagic spots. There were some yellowish spots with a slight elevation in the centre.
13	7 months' pregnancy.	G92	48	999	3	13-9-32 Immature at that time	Do.	4	5	20	4-15 p.m. 25-10-32	54	Pos.	Both ovaries converted into modular hæmorrhagic masses.
14	8 months' pregnancy.	H7	Isolated Mature	...	...	Nil	Catheter specimen	6	4 – 5	29	10 a.m. 3-10-31	43·5	Pos.	
15	8 months' pregnancy.	H9	Do.	...	...	Nil	Ordinary specimen	5	4½ – 6	26½	10-30 a.m. 23-10-31	46·5	Pos.	
16	8 months' pregnancy.	H10	Do.	...	...	Nil	Do.	5	5 – 6	28	10-30 a.m. 25-10-31	46·5	Pos.	

Serial No.	PATIENT.	Experiment No.	ANIMAL.				Substance injected.	INJECTIONS.			LAPARATOMY.			REMARKS.
			Serial No.	Wt. in grms.	Age in months.	Previous Laparatomies.		No.	Amt. at 1 injection in c.c.	Total Amount.	Time and date.	Hrs. after 1st injec.	Result	
17	8 months' pregnancy.	G8	8	1028	2·5	Nil	Ordinary specimen	6	4 – 5	28½	2-30 p.m. 4-4-32	52	Pos.	Both ovaries converted into an irregular nodular hæmorrhagic mass.
18	8 months' pregnancy.	G9	9	1398	2·5	Nil	Do.	6	4 – 5	29½	3 p.m. 4-4-32	52·5	Pos.	Both ovaries showed many hæmorrhagic spots but not converted into the sort of masses as in Exp. 17 (G8).
							In Labour.							
19	8th para in labour.	H16	Virgin	...	4	Nil	Do.	6	5	30	10 a.m. 17-12-31	48	Pos.	Only one partially hæmorrhagic follicle on the ovary. This may be due to the endocrine changes during labour.

TABLE V.—*Cases of definite pregnancy—18 c.c. 30 hour Technic—10 Cases All Positive. Early Pregnancy—First five months.*

Serial No.	PATIENT.	Experiment No.	ANIMAL.				Substance injected.	INJECTIONS.			LAPARATOMY.			REMARKS.
			Serial No.	Wt. in grms.	Age in months.	Previous Laparatomies.		No.	Amt. at 1 injection in c.c.	Total amount.	Time and date.	Hrs. after 1st injec.	Result	
1	7 weeks' pregnancy.	G28	13	1298	3·75	9-5-32	Ordinary specimen	3	6	18	4-45 p.m. 10-6-32	29	Pos.	Ovaries showed pinkish (not dark purple as usual) hæmorrhagic follicles and freshly ruptured follicles.
2	2½ months' pregnancy.	G50	18	1762	5	28-6-32 Left ovary removed	First morning specimen	2	7	14	4-30 p.m. 27-7-32	25	Pos.	Right ovary showed four follicle definitely enlarged, with slight congestion only. One follicle at the top, however, showed definite hæmorrhage into it.
											3-30 p.m. 28-7-32	48	Pos.	The ovary showed many more follicles

Serial No.	PATIENT.	Experiment No.	ANIMAL.				Substance injection.	INJECTION.			LAPARATOMY.			REMARKS.
			Serial No.	Wt. in grms.	Age in months.	Previous Laparatomies.		No.	Amt. at 1 injection c.c.	Total Amount.	Time and date.	Hrs. after 1st injec.	Result	
														and hæmorrhage into them was better marked.
3	3 months' pregnancy Hyperemesis.	G27	4	1465	7	18-3-32+ 5-5-32+	First morning specimen	2	5	10	3-30 p.m. 9-6-32	30·5	Pos.	Right ovary showed one purplish hæmorrhagic spot, and another pinkish. Left ovary showed one pinkish spot only.
4	3 months' pregnancy. Hyperemesis.	G33	24	1760	...	Nil	Do.	3	5½-6½	18	2-45 p.m. 24-6-32	29·75	Pos.	
5	5½ months' pregnancy.	G16	4	1608	5·75	18-3-32+	Do.	3	5½	16½	3 p.m. 5-5-32	30·5	Pos.	

Advanced Pregnancy—Foetal Heart Heard.

6	Pregnancy 6th month.	G32	25	1522	...	Nil	First morning urine	3	5-6½	17	4-30 p.m. 22-6-32	31·75	Pos.
7	Pregnancy 32 weeks.	G30	15	1087	...	11-5-32 –	Do.	3	5½-6	17½	4-30 p.m. 17-6-32	32	Pos.
8	Pregnancy 34 weeks.	G31	22	1060	...	Nil	Do.	3	6	18	4 p.m., 18-6-32	31	Pos.
9	Pregnancy ? weeks. Slight bleeding since 4 days. Foetal heart heard.	G38	28	1162	...	Nil	Do.	3	6-7	20	4-45 p.m. 6-7-32	32	Pos.
10	Pregnancy ? weeks. Foetal heart heard.	G39	26	1220	...	Nil	Do.	3	6-7	19	4-15 p.m. 8-7-32	30·5	Pos.

TABLE VI.—*Cases of Definite Pregnancy—Injection of Blood Serum 3–4½ c.c. read at 25·5–27·75 hours. 4 Cases All Positive.*

Serial No.	PATIENT.	Experiment No.	ANIMAL.				Substance injected.	INJECTIONS.			LAPARATOMY.			REMARKS.
			Serial No.	Wt. in grms.	Age in months.	Previous Laparatomies.		No.	Amt. at 1 injection in c. c.	Total amount.	Time and date,	Hrs. after 1st injec.	Result.	
1	Pregnancy 7 months. Foetal heart heard.	G51	28	1287	...	6-7-32+	Serum. Blood allowed to stand for some hours and serum utilised.	2	1 – 2	3	4-30 p.m. 28-7-32	27	Pos.	
2	Pregnancy 7 months' Foetal heart heard.	G56	36	1030	...	Nil	Do.	2	1·5	3	3-30 p.m. 4-8-32	26·5	Pos.	
3	Pregnancy 36 weeks, Foetal heart heard.	G53	39	1060	...	Nil	Do.	2	2	4	2-45 p.m. 30-7-32	25·5	Pos.	
4	Pregnancy 9th month, Foetal heart heard.	G66	26	...	...	8-7-32+ 3-8-32 –	Do.	2	1 – 3½	4½	5-15 p.m. 2-9-32	27·75	Pos.	

TABLE VII.—*Definitely Non-pregnant Patients—24 c.c.—48 hour Technic—All Negative.*

Serial No.	PATIENT.	Experiment No.	ANIMAL.				Substance injected.	INJECTIONS.			LAPARATOMY.			REMARKS.
			Serial No.	Wt. in grms.	Age in months.	Previous Laparatomies.		No.	Amt. at 1 injection in c.c.	Total amount.	Time and date.	Hrs. after 1st injec.	Result	
1	Right ovarian cyst, left tube and ovary matted together by inflammation. Fibroid in the lower part of the posterior wall. Performed for academical interest only.	Haff. 4	Isolated mature female.	...	...	Nil	Catheter specimen collected just before operation	6	5	30	9-30 a.m. 18-9-31	48	Negative	
2	Left cystic ovary and fibrosis uteri, Performed for academical interest only.	Haff. 5	Do.	...	...	Nil	Do.	...	...	...	...	48	Neg.	
3	Mrs. R. V. age 30. Complaint: pain in lower abdomen, more marked since 5 days. Before this attack lasting 2 or 3 days. Menst. Hist: regular 3:30 but scanty. L.M.P. 10 days ago	Haff. 19	Virgin female.	...	3·5	Nil	Catheter specimen collected during outdoor examination.	5	4-5½	24½	30-1-32	48	Neg.	Though the Surgeon thought it right to operate on this case being sure it required operation even if she was pregnant, it illustrates clearly how easily the breast signs and

Serial No.	PATIENT.	Experiment No.	AINMAL.				Substance injected.	INJECTIONS.			LAPARATOMY.			REMARKS.
			Serial No.	Wt. in grms.	Age in months	Previous Laparatomies.		No.	Amt. at 1 injection in cc.	Total amount.	Time and date.	Hrs. after 1st injec.	Result	
	Bowels costine during attacks of pain. Micturition painful and difficult. Married 7 yrs. sterile. P. A. tumour situated in the hypogastrium, in the middle line, extending to the umbilicus. Not reduced after catherisation, though 10 oz. of urine were withdrawn. Foetal heart not heard, ballotement and intermittent uterine contractions negative. Breasts secretion present but no change in areola, no Montgomery's tubercles. P V. cervix points backwards nulliparous. Lower abdomen occupied by a tumour													median cystic tumour could be mistaken for pregnancy. The ovulation test was negative and thus proves its usefulness.

	chiefly cystic, partly solid connected with the uterus ? and tender. Laparatomy : bilateral ovarian cysts. Right one much larger occupied the right iliac fossa and the hypogastrium dissecting into the broad ligament. Fallopian tube stretched over it.												
4	Ovarian tumour—clinically, malignant ? Histologically adenocarcinoma. Performed for academical interest only.	G.S.M.C. XXXIV	19	1427	...	28-5-32+	1st morning specimen	4	6-6½	25	12-30 p.m. 26-6-32	51·75	Neg.	The ovaries showed ripe graffian follicles larger on the left side. This test was done to see whether a malignant ovarian tumour would give a positive reaction.
5	Multilocular cyst of the ovary. Performed for academical interest only.	G.S.M.C. LXXXVII	46	2152	7·25	1-9-32 + Left ovary removed	Do.	3	7-7·5	21·5	4-30 p.m. 11-10-32	54·5	Neg.	
6	Case of dysfunctional uterine bleeding. Periods of amenorrhoea followed by continuous	G.S.M.C. LXXXI	43	1740	...	31-8-32—	Do.	2	7-8	15	3 p.m. 4-10-32	73	Neg.	This case shows that this endocrine disturbance does not give positive test.

Serial No.	PATIENT.	Experiment No.	ANIMAL.				Substance injected.	INJECTIONS.			LAPARATOMY.			REMARKS.
			Serial No.	Wt. in grms.	Age in months.	Previous Laparatomies.		No.	Amt. at 1 injection in c.c.	Total amount.	Time and date.	Hrs. after 1st injec.	Result	
	bleeding for a long time. Bilateral ovarian enlargement.													
7	Supravaginal hysterectomy with both appendages. Performed 24 hours before collection of sample.	G.S.M.C. LXXIV.	42	1427	6·5	6-8-32+	First morning specimen urine.	3	5 – 7	18	5 p.m. 19-9-32	53	Neg.	This shows that post castration changes do not produce (at least within 24 hours) a+test.
8	Same as above—11 days after the operation.	G.S.M.C. LXXVIII.	29	...	...	18-7-32+ 13-8-32+ Lt. ovary removed.	Blood serum.	3	3 – 4	11	2-15 p.m. 29-9-32	46	Pos.	Right ovary showed one enlarged smoky graffian follicle and two enlarged graffian follicles. In this case the animal had only one ovary. It appears to us that the large amount of serum was just insufficient to give a positive test.

9	Supravaginal hysterectomy with both appendages.	G.S.M.C. LXXXV	18	1827	7·5	28-6-32 – Left ovary removed. 28-7-32+	First morning specimen of urine.	3	7½ – 8 23½	4-30 p.m. 10-10-32	72	Neg.	
10	Mrs. V. P. age 22. Complaint: pain in the lower abdomen and irregularly profuse menstruation. P. V. uterus freely moveable, normal in size; a lump in the right fornix, size of a duck's egg, ectopic gestation? At a later examination the lump had completely disappeared.	G.S.M.C. XXXV	18	1462	4	Nil.	Do.	3	6½ – 8 22·5	3-45 p.m. 28-6-32	54	Neg.	In both these cases the suggestion of ectopic gestation was there, but the ovulation test agreed with the future progress of the patients.
11	Mrs. S. K. age 25, 3 months' amenorrhoea followed by haemorrhage and passage of clots. In another hospital for a month (diagnosis in that hospital not known). P. V. a pulsating lump to the right of the uterus, tubal pregnancy? Later the	G.S.M.C. XLVI	30	1207	...	Nil	Do.	4	5 – 6 21·5	3-30 p.m. 21-7-32	48	Neg.	

Serial No.	PATIENT.	Experiment No.	ANIMAL.				Substance injected.	INJECTIONS.			LAPARATOMY.			REMARKS.
			Serial No.	Wt. in grms.	Age in months.	Previous Laparatomies.		No.	Amt. at 1 injec. in c.c.	Total Amount.	Time and date.	Hrs. after 1st injec.	Result	
	lump had diminished greatly and the bleeding stopped. Patient discharged.													
12	Clinically, enlargement of the uterus, cystic to the feel. pregnancy? New growth? After operation proved to be cystic degeneration in a fibroid.	G.S.M.C. XVIII	13	1330	2·75	Nil	First morning specimen of urine.	4	5 – 6	22	3 p.m. 9-5-32	49·25	Neg.	Both these cases illustrate the difficulty of diagnosing a fibroid from pregnancy when the tumour grows uniformly and owing to degeneration becomes soft. In both these cases, even on opening the abdomen, the softness and more or less uniform enlargement of the uterus was
13	Mrs. J. S. age 35. Irregular bleeding, pain and swelling in the lower abdomen, all of one year's duration. Married in childhood, widow for 5 or 6 years. Three full term labours. Fever in the puerperium at every delivery. Men-	G.S.M.C. LXII.	37	1135	...	Nil	Second morning's specimen of urine and a fresh specimen next day.	4	4½ – 6	23·5	2-30 p.m. 27-8-32	47·5	Neg.	

	strual Hist. previous 4-3-30; present irregular bleeding. P. A. tumour of the size of a cocoanut rising from the pelvis, freely moveable tense and cystic to the feel, dull on percussion. P. V. cervix split transversely more on the right, uterus cannot be defined; resistance on left side—small ovarian cyst. Tumour can be lifted up from the pelvis, cervix moves with it in whichever direction it is moved. Per speculum-cervix split, leading into the right fornix. Patient bleeding through the cervix. Pregnancy? fibroid? Operation cystic degeneration in a fibroid.													so deceptive that I was questioned as to the accuracy of the test. In the 2nd case (G. S. M. C. LXII) the operator grew more suspicious when a certain amount of fluid (resembling liquor amnii but coming in fact from the degenerating tumour) escaped. But to her great satisfaction, on opening the uterus, a degenerating fibroid was discovered.
14	Mrs. K. V. 1½ months' abortion? Amenorrhoea since	G.S.M.C. V	5	...	4·25	Nil	Ordinary first morning spe-	5	5-6	27½	10 a.m. 20-3-32	47	Neg.	

Serial No.	PATIENT.	Experiment No.	ANIMALS.				Substance injected.	INJECTION.			LAPARATOMY.			REMARKS.
			Serial No.	Wt. in grms.	Age in months.	Previous Laparatomies.		No.	Amt. at 1 injection in c.c.	Total amount.	Time and date.	Hrs. after 1st injec.	Result	
	then for 1½ months. P. V. uterus enlarged slightly, early pregnancy? The patient started bleeding and was curetted. Scrapings showed no chorionic tissue.						cimen urine							
15	Mrs. E. K. age Since the delivery of a 12 pound baby, she had irregular bleeding for which she was curetted and was better. In May, 1931, after being six weeks since her last menstrual period, she had a sudden hæmorrhage. The doctor called in thought she had an ectopic gestation. Taken to hospital curretted without relief. Curet-	Haff XVII	Virgin	...	4·5	Nil	First morning specimen before operation	6	4	24	11-45 a.m. 8-1-32	44	Neg.	This case shows the deceptive nature of the microscopic findings in such cases and proves that the biological tests give a more reliable results.

ted again at another hospital without relief. On admission nothing except a rather bulky uterus was found. Curetted—pathology report: "sections of the curetted material showed evidence of malignancy:—presence of infiltration of muscle by pale staining cells (Langhan's cells?) showing pleomorphism of nucleii: and of syncytial masses in between similar cells elsewhere." A complete hysterectomy was performed on 8-1-32. Pathology report:—the finding from the curetted material cannot be confirmed. The uterus shows placental tissue adherent to it. There is deeply spreading chronic inflammatory process in the muscularis.

TABLE VIII.—*Cases of Ectopic Gestation 24 c.c. 48 Hour Technic—7 Cases (6 positive ; 1 negative).*

Serial No.	PATIENT.	Experiment No.	ANIMAL.				Substance injected.	INJECTIONS.			LAPARATOMY.			RAMARKS.
			Serial No.	Wt. in grms.	Age in months.	Previous Laparatomies.		No.	Amt. at 1 injec. in c.c.	Total amount.	Time and date.	Hrs. after 1st injec.	Result	
1	Mrs. S. F. age 21, Complaint : attacks of bleeding per vaginum with crampy pain for 2½ months. She had gone 6 days over her period before the complaint started. Periods regular 8/30 before the present complaints. Married 4 years, sterile. P. V. uterus bulky, somewhat soft, upright. Tubo ovarian swelling on right side with pulsation underneath. Left fornix free. Laparatomy : pelvic cavity filled with blood clots. *Old Broad Ligament*	G.S.M.C. I	1	...	4-25	Nil	Specimen of urine just before operation	6	4-5	27½	3 p m. 19-2-32	48	Neg.	The absence of living chronic tissue explains the negative reaction.

	Haematoma (Right side) Sections showed no chorionic tissue.													
2	Mrs. S. N. age 35. Attacks of pain in lower abdomen lasting for 2 hours since 20 days. Menst. Hist : 5·30 type. For the last 3 months scanty lasting 1–2 days. L.M.P. 20 days back-slight blood-stained discharge. Husband died 3 years ago. Three full term children. One three months' abortion 4 years back. P. V. cervix points downwards and backwards, uterus retroverted, tender, normal in size. Operation :—*right tubal abortion*. Microscopic examination revealed *chorionic tissue.*	Haff XX	Virgin	...	4	Nil	Urine taken a few hours after operation	5	5-5½	25·75	10 a.m. 7-2-32	42·75	Pos.	See Plate III. The misleading history and the smallness of the sac led to the mistake in diagnosis. This case indicates how the test is useful even in the diagnosis of such early cases.

Serial No.	PATIENT.	Experiment No.	ANIMAL.				Substance injected.	INJECTION			LAPARATOMY			REMARKS.
			Serial No.	Wt. in grams.	Age in months.	Previous Laparatomies.		No.	Amt. at 1 injec. in c.c.	Total Amount.	Time and date.	Hrs. after 1st injec.	Result	
3	Married 4 yrs. sterile. Went 13 days over her period which was usually 2-3/28 type. Then she had bleeding for 4 or 5 days with pain. P. V. pulsatile mass in the right fornix. Rabbit ovulation test performed—positive Operation decided upon. *Right haematosalpinx Few sections showed no chorionic tissue.*	G.S.M.C. XV	Mature animal littered 1½ months ago. Not crossed since XI	1313	...	Nil	First morning specimen	4	4-6	19·5	2-45 p.m. 29-4-32	48-25	Pos.	It is quite likely that if more sections were taken living chronic tissue could have been detected. It shows that a small amount of such tissue is enough to give a positive test.
4	This was a case of ovarian pregnancy. As it is to be shortly published, we do not describe it here. (Purandare and	G.S.M.C. XXII	17	1495	3	Nil	5 c.c. of morning specimen before oparation & cathe-	5	5-6	27	12-15 p.m. 16-5-32	46	Pos.	

	Dhaygude in *Bom. Med. Journ.*)						ter specimen after operation							
5	Mrs. J. G. age 40. Complaint :—Went 10 days over her period and then began getting pain in the lower abdomen and a blood stained discharge which had lasted a month on admission. Previous to this period always regular 3-5/22 type. Obstetric Hist : 3 full term normal labours, last 3 yrs. ago. Fever after 2nd delivery for a month. P. V. Cervix very soft, uterus anteflexed. A very tender and painful lump in the left fornix. Urine sent for biological test. Patient collapsed before the result of the test could be given. Operation : *left tubal rupture.*	G.S.M.C. LXIV	47	1807	6	Nil	First morning specimen	3	5-7	19	3-30 p.m. 1-9-32	52	Pos.	Attention may be drawn to the fact that the patient was in the hospital for 3 days before the urine was sent for the test. If the urine was sent to us for examination on admission the collapse might have been avoided.

Serial No.	PATIENT.	Experiment No.	ANIMAL.				Substance injected.	INJECTIONS.			LAPARATOMY.			REMARKS.
			Serial No.	Wt. in grams.	Age in months.	Previous Laparatomies.		No.	Amt. at 1st injec. in c.c.	Total Amount.	Time and date.	Hrs. after 1st injec.	Result	
6	Mrs. S. K., age 22. 30-8-32. Complaint: went 6 days over her period and then started getting pain in the lower abdomen and bleeding per vaginum. Menst. Hist: 8/30 type. Last regular menst. period 42 days ago. Married 12 yrs. back, one full term labour 5 yrs. back. Fever for a fortnight in the puerperium. P. V. uterus anteverted, lump in the right fornix tender and painful, cannot be clearly made out on account of rigidity. Patient kept quietly in bed. 1-9-32. ovulation test+2-9-32. patient had severe	G.S.M.C. LXV	46	2109	6	Nil	Ordinary second morning specimen	4	6–8	26	10 a.m. 1-9-32	44	Pos.	Right ovary showed 2 freshly ruptured follicles and 1 pinkish purple partially hæmorrhagic follicle. Left ovary showed 2 freshly ruptured follicles and 2 pinkish purple partially hæmorragic follicles.

	pain and collapsed. Operated at once. *Right tubal abortion.* Left tube tortuous, Probe did not pass. Left salpingectomy done.											
7	Mrs. B. D. age 30. Complaint: pain in the lower abdomen, bleeding per vaginum for a fortnight. Menst. Hist: previous cycle 4-5/30 regular. She went a fortnight over her period and then the present bleeding and pain started. Obst. Hist; 6 full term children last 6 yrs. ago. Puerperal fever after the last confinement. Bowels costive. P. V. uterus deviated to the left. A mass on the right side. Douglas's pouch full. Operation: 10-11-32—*tubal abortion incomplete.*	G.S.M.C. CII	28	1592	...	6-7-32 + 28-7-32 + 6-9-32 — 18-10-32 —	Specimen of urine collected 24 hours after operation	3	5-7	18	4-30 p.m. 14-11-32	55	Pos.

TABLE *IX.—Cases of Abortions in Various Phases.*

Serial No.	PATIENT.	Experiment No.	ANIMAL.				Substance injected.	INJECTIONS.			LAPARATOMY.			REMARKS.
			Serial No.	Wt. in grms.	Age in months.	Previous Laparatomies.		No.	Amt. at 1 injec. in c.c.	Total Amount.	Time and date.	Hrs. after 1st injec.	Result	
1	Mrs. W. H., age 27, para VI; L. M. P. 18-3-32; bleeding since 21-5-32; uterus cleared out on 27-5-32 for increased bleeding, when a foetus and fresh placental tissue were removed *threatened abortion inevitable.*	G XXIII	19 Littered on 17-5-32	1324	...	Nil	Ordinary 1st morning specimen of 26-5-32	4	6	24	2-30 p.m. 28-5-32	53	Pos.	Two dark red spots on the left ovary. Bright red spots on both ovaries only one of which showed definitely conical projection.
2	Mrs. J. D. age 32, 6 full term labours last 2½ years ago, all normal admitted for irrigular haemorrhage for 2 months preceded by 3 months' amenorrhoea; 21-11-31 P. V. uterus retroverted can be raised, enlarged to	H13	Isolated mature	...	...	Nil	Ordinary 1st morning specimen of 20-11-31	6?	5	30?	22-11-31	48	Neg.	

	the size of 2 months' pregnancy. Internal os closed; Dilated & curretted on the same day Os easily dilatable, remnants of a degenerated ovum and placenta removed. *Missed abortion.*												
3	Mrs. B., age 40; amenorrhœa of 9 months pain in the abdomen for a fortnight On closer questioning the patient said she had 3 attacks of bleeding and pain in the abdomen during this period of amenorrhœa. Menst. Hist.—very indefinite, very irregular according to her. Obst. Hist. 7 children, 3 living, 4 dead. Last delivery 3 years back. Peurperium normal. Breasts not active P. V. cervix points backwards, somewhat soft, uterus enlarged to the size	G36	23	1807	...	Nil	First morning specimen	4	5-8	24	8-15 a.m. 30-6-32	44·5	Pos. weak	Right ovary showed one enlarged graffian follicle which showed no sign of rupture or hæmorrhage, three follicles showed conical projection and umbilication but only one of them showed hæmorrhage at the umbilication. Left ovary showed two follicles with conical projection and umbilication, but only one showed slight hæmorrhage. It may be noted here that with 24 c.c. 48 hr. technic, conically projecting dark purplish hæmorrhagic spots are

Serial No.	PATIENT.	Experiment No.	ANIMAL				Substance injected.	INJECTIONS.			LAPARATOMY			REMARKS.
			Serial No.	Wt. in grms.	Age in months.	Previous Lapara-tiomies.		No.	Amt at 1 injec. in c.c.	Total Amount.	Time and date.	Hrs. after 1st injec.	Result	
	of *4* months' pregnancy, freely movable uniform, ballotement not felt. Per speculum: cervix bluish. (see last column for our report). 1-7-32 uterus emptied of its contents by ovum forces after dilatation. Contents showed a degenerated foetus, the placental tissue was degenerated, there were a few vesicles but the pathological report said they did not show malignancy. *Missed abortion.*													always seen in cases of definite pregnancy, even when it is early. It is very likely that if the test was performed with 5 c.c. 16 hour technic it would have been negative: and thus it would have been difficult to diagnose this from a non-pregnant condition like a fibroid. We reported it is possible, that the patient has a very small amount of hormone on account of foetal death and destruction of most of the chorionic tissue.
4	Mrs. P. N., age 26 13-7-32 admitted for fever, giddiness, swel-	G43	25	1619	...	22-6-32 +	Ordinary morning specimen	4	5-7	24	2-15 p.m. 17-7-32	50	Pos.	Left ovary showed one large purplish black hæmorrhagic spot and

	ling of the feet. 8 months pregnant—uterus corresponded to 7 months. Fœtal movements not felt by the patient nor by the attendant for the last 15 days. 18-7-32 bones of the skull found to be overlapping by an internal examination. Labour induced. Macerated fœtus delivered. *Death of foetus in utero.* A healthy looking portion of the placenta was sectioned and showed *healthy chorionic tissue.* It is possible that there was sufficient chorionic tissue in biologic contact with the uterus to give a positive test, yet insufficient for the existence of the fœtus.													three freshly ruptured follicles. Right ovary showed three freshly ruptured follicles.
5	Mrs. S. P., age 28 said to be 5 months' pregnant, started getting pain at 7-30 a.m. on 8-7-32 and also bleed-	G41	16	1302	4·5	14-5-32 ? 14-6-32+	Catheter specimen at 12-15 p.m. on 9-7-32.	4	4 – 5	19	5 p.m. 11-7-32	51·5	Pos.	Both ovaries were converted into large hæmorrhagic masses.

Serial No.	PATIENT.	Expirement No.	ANIMAL.				Substance injected.	INJECTIONS.			LAPARATOMY.			REMARKS.
			Serial No.	Wt. in grms.	Age in months.	Previous Laparatomies.		No.	Amt. at 1 injec. in c.c.	Total Amount.	Time and date.	Hrs. after 1st injec.	Result	
	ing; while going home she fell down on the way and she states she expelled the foetus at that time.													
	Menst. Hist. regular before 5 months. L. M. P. 5 months back. Obst. Hist:—first normal female child died after 9 months 1½ yrs. back. Temp. 97. Pulse: 124.	G49	34	1072	...	Nil	Same specimen kept in cold storage.	4	4	16	3-15 p.m. 23-7-32	46	Pos.+	Right ovary changed into a sort of haemorrhagic mass. Left ovary similarly changed into a smaller and more spherical mass.
	Slight bleeding per vaginum on admission. Breasts active. P. V. os two fingers dilated, uterus enlarged and tender. Pieces of ovum felt in the os: grape like? cysts expelled.	G45	19	1642	...	28-5-32+ 26-6-32 -	First morning specimen of 18-7-32	3	6	18	5-15 p.m. 20-7-32	50	Neg.	No sign of ovarian stimulation.

	9-7-32 Temp : normal. Pulse: 128. Volume not improving, slight bleeding throughout. Lungs:—rhoncii all over. 11-7-32 dilatation and curetting. Placental tissue removed, no vesicles seen. But it was very adherent at one spot according to the physician. Path. report:—sections show characters of a neo-plastic growth, chorion carcinomax? Patient could not be traced.	G48	24	1715	...	24-6-32+ left ovary removed	Same specimen kept in cold storage.	3	5 – 7	18	...	27 or more	Neg.	The animal at the first injection on 21-7-32 at 5-45 p.m. and was alive at 9 p.m. 22-7-32, and was found dead at 8 a.m. 23-7-32. Thus the animal lived at least 27 hours and as there was no definite ovarian change, we took it as a negative reaction.
6	Mrs. P. S. age 40, 18-7-32 admitted for acute spasmodic pain in the lower abdomen and fever for the last 4 days. Widow for 16 yrs. 4 full term labours, last 16 yrs. ago. Puerperal fever after last delivery. Menst. Hist: 4-5/30 regular. L. M. P. 20 days back, profuse bleeding lasting 7	G47	40	1712	...	Nil	Ordinary afternoon specimen	3	5-6	16·5	4 p.m. 21-7-32	48	Pos.	Left ovary showed three large Graffian follicles. Right showed one at the upper pole and another in the middle: at the lower pole there was a conically projecting and umbilicated graffian follicle. It is possible that this patient had an incomplete abortion and that thus there was a

Serial No.	PATIENT.	Experiment No.	ANIMAL.				Substance injected.	INJECTION.			LAPARATOMY.			REMARKS.
			Serial No.	Wt. in grms.	Age in months.	Previous Laparatomies.		No.	Amt. at 1 injection in c.c.	Total amount.	Time and dated.	Hrs. after 1st injec.	Result	
	days. The patient, however, seemed to be very vague about it. P. V. patient very tender on examination, all fornices full, uterus cannot be differentiated, cervix patulous. Blood on examining finger. Operation 19-7-32—general peritonitis—drained—patient expired after a few hours.													little amount of hormone in the circulation.
7	Mrs. C. V., age 30. Complaint :—Griping pain in lower abdomen for 8 days. Bleeding per vaginum (after amenorrhoea of 3 months) for last 6 days. Previous to this menstruation normal	G57	42	1715	5	Nil	First morning specimen	4	5-7	24	8-30 a.m. 6-8-32	43	Pos.	Right ovary showed one purplish black hæmorrhagic follicle at the top and one pink, conical, umbilicated follicle. Left ovary showed only a pinkish conical follicle. Cases 6 and 7

and regular. Married 20 years back. No conception. Widow since last 7 years. Secretion in both breasts. Lower abdomen rigid and tender, a mass felt in left iliac fossa. P. V. uterus anteverted and larger and softer than normal, tender. A very tender mass in the left fornix, free from the uterus. Right and posterior fornices empty. At a later examination the lump in the left fornix was found to be harder. Diagnosis—parametritis, due to infection after abortion. 6-8-32 patient developed tetanus: but improved with treatment. 31-8-32 P. V. uterus retroverted cannot be completely brought forwards. Fornices clear, a small swelling in the abdominal wall on left side.													illustrate how an infection after an incomplete abortion may mimic ectopic gestation in many aspects and how the biological tests may also be deceptive.

TABLE X.—*Cases of Hydatid Mole and Chorionepithelioma.*

Serial No.	PATIENT.	Experiment No.	ANIMAL.				Substance injected.	INJECTIONS.			LAPARATOMY.			REMARKS.
			Serial No.	Wt. in grms.	Age in months.	Previous Laparatomies.		No.	Amt. at 1 injec. in c.c.	Total Amount.	Time and date.	Hrs. after 1st injec.	Result	
1	Passed a vesicular mole on 15-8-31 patient quite well getting normal periods.	H12	Isolated mature	...	...	Nil	Catheter specimen of 2-11-31	5	1-4½	18-19	10·15 a.m. 5-11-31	48·25	Neg.	
2	Passed a vesicular mole on 22-9-31. 23-9-31 exploration of the uterine cavity showed no evidence of malignancy. 14-12-31 came to O. P.D. for leucorrhoea. Complete examination revealed nothing except an erosion.	H15	Do.	...	...	Nil	Specimen of 14-12-31	6	4½-5	28	17-12-31	48	Neg.	
3	Mrs. B. passed a vesicular mole on 10-2-32 (induced by tents). Mole expelled entirely.	G2	2	...	4	Nil	Specimen of 9-3-32	5	...	25·5	3 p.m. 11-3-32	47	Pos.	

	21-2-32 progressed well, bleeding practically stopped. Discharged. Bleeding started again 8 days after discharge from the hospital. 17-3-32 curetted—scrapings showed no evidence of malignancy. Patient all right at present.	G12	10	1827	4·25	Nil	Specimen of 14-4-32	5	...	26	3 p.m. 16-4-32	48	Neg.	Many transparent enlarged Graffian follicles, but no sign of haemorrhage or rupture.
		G20	15	1151	...	Nil	2nd morning specimen of 9-5-32	5	4½-6	26	4-30 p.m. 11-5-32	51	Neg.	Both ovaries showed three enlarged follicles, pinkish, but no sign of haemorrhage or rupture. They were not conical but flat-topped.
4	Mrs. Y. S. R. 3-6-32. ***Passed a vesicular mole*** (induced by tents, mole expelled entirely). She was progressing well and had a normal period after some irregular hæmorrhage. On the third day of her 2nd normal period (21-11-32) she had a sudden ***intraperitoneal flooding***. She was soon operated and the surgeon stopped a bleeding point at the posterior wall of one of the cornu of the uterus by a mattress suture. The patient	G29	16	1163	3·75	14-5-32 ?	1st morning specimen of 12-6-32	3	4-6	15	12 noon 14-6-32	48·75	Pos.	
		G55	41	1735	4	Nil	Specimen of 3-8-32	4	6	24	5 p.m. 5-8-32	55	Pos.	Before the intraperitoneal flooding.
		G71	34	1397	...	23-7-32 ++	Specimen of 9-9-32	3	7-9	24	12-15 p.m. 11-9-32	49	Neg.	
		G109	58	1373	...	Nil	Specimen of 23-11-32	2	7	14	3-15 p.m. 25-11-32	47	Neg.	After intraperitoneal flooding.
		G111	55	1190	...	Nil	Specimen of 29-11-32	1	2	2	3-30 p.m. 1-12-32	47·5	Neg.	

Serial No.	PATIENT.	Experiment No.	ANIMAL				Substance injected.	INJECTION			LAPARATOMY.			REMARKS.
			Serial No.	Wt. in grms.	Age in months.	Previous Laparatomies.		No.	Amt. at 1 injec. in c.c.	Total Amount.	Time and date.	Hrs. after 1st injec.	Result	
	is doing well and had a normal period from 30-12-32 to 3-1-33.													
5	Mrs. T. S. Y., age 18, para 1 : amenorrhoea of 5½ months : bleeding per vaginum. P. A. fundus two fingers below the umbilicus. P. V. os admits just the tip of the index finger—later one finger dilated—few vesicles passed. *Mole expelled* spontaneously on 13-10-32.	G91	44	1600	...	7-9-32 – Left ovary removed	Specimen of 20-10-32	2	6	12	9-30 a.m. 22-10-32	43·5	Pos. +++	The right ovary showed one haemorrhagic spot as seen usually. About ½ doz. yellow luteinized spots with signs of rupture at the top in some. There was one very large graffian follicle with no sign of haemorrhage or rupture. See plate V.
6	Mrs. R. J. Case of *Chorionepithelioma* (reported by Major W. C. Spackman in the *Bom. Med. Journ.*) So not des-	G58	19	1536	...	28-5-32+ 26-6-32 – 20-7-32 –	1st Specimen after operation and first morning specimen	3	6	18	5 p.m. 8-8-32	52	Pos.	Right ovary showed 5 or 6 purple haem. Spots, one freshly ruptured follicle and two pinkish elevated follicles. Left ovary

	cribed here. 5-8-32 Hysterectomy. See Plate IV.						after operation							showed one large purple haem. spot and one freshly ruptured follicle.
		G61	25	1595	...	22-6-32 + 17-7-32 +	1st morning specimen of 23-8-32	4	5-7	24	4-30 p.m 25-8-32	52·5	Pos.	Both ovaries showed only one haemorrhagic follicle. There were some others, which were rather enlarged but showed no sign of haemorrhage or rupture.
		G89	28	1535	...	6-7-32 + 28-7-32 + 6-9-32 —	1st morning specimen of 16-10-32	4	5-7	24	4-30 p.m. 18-10-32	54·5	Neg.	Both ovaries showed ripe graffian follicles rather enlarged but no sign of haemorrhage or rupture.

Experiments with Increasingly small amounts of Urine of Moles & Chorionepithelioma: Injection of Fluid from Vesicular Mole and Implant of Tissue from Moles.

7	*Chorionepithelioma.* Mrs. M. A. G. age 30. 21-6-32. Complaint: bleeding per vaginum, following a full term still birth, 3 months back: pain in the lower abdomen and back ache. Obst.	G69	41	...	5·25	5-8-32+	Specimen of 6-9-32	3	6·5-8	21·5	5-30 p.m. 8-9-32	55	Pos.	
		G73	40	1750	...	21-7-32+	Specimen 14-9-32	1	4 c.c. of 1 c.c. of urine dilu-	½	5-15 p.m. 16-9-32	54	Pos.	

Serial No.	PATIENT.	Experiment No.	ANIMAL.				Substance injected.	INJECTION.			LAPARATOMY.			REMARKS.
			Serial No.	Wt. in grms.	Age in months.	Previous Laparatomies.		No.	Amt. at 1 injection in c.c.	Total Amount.	Time and date.	Hrs. after 1st injec.	Result	
									ted to 8 c.c. with saline					
	Hist: married 10 years back, 4 full term normal deliveries. Last 3 months ago, still born and macerated. Fever in the last confinement starting on the first day of the delivery, patient free from fever only two weeks back.	G76	30	1487	...	21-7-32 — 18-8-32 + Left ovary removed	Specimen of 24-9-32	1	5 c.c. of 5 in 100	¼	4-30 p.m. 26-9-32	54·5	Pos.	
	Ment. Hist: first period at age of 14, previous cycle 7-30. Continuous bleeding since the delivery 3 months ago. Bowels and micturition normal. P. V. Uterus retroverted larger than normal, can be brought forwards, os patulous. Appendages normal.	G79	25	1567	...	22-6-32 + 17-7-32 + 25-8-32 +	Specimen of 28-9-32	1	4 c.c. of 4 in 64	¼	2-15 p.m. 30-9-32	52	Pos.	

Refused dilatation and curetting, discharged against advice.	G80	37	1342	...	27-8-32 −	Specimen of 28-9-32	1	1 c.c. of 4 in 64	1/16	3 p.m. 30-9-32	52·5	Pos.
16-8-32 readmitted for fever with rigors and cough. Foul vaginal discharge and profuse bleeding at times after her discharge from the hospital on 27-6-32.	G82	26	...	...	8-7-32 + 3-8-32 − 2-9-32 +	Do.	1	1 c.c. of 2 in 64	1/32	3-30 p.m. 5-10-32	47	Pos.
P. V. uterus retroverted, brought forward, very tender and painful. Foul discharge on examining finger.	G83	47	...	7	Right ovary removed	Do.	1	2 c.c. of the 2 in 64 were diluted to 8c.c. & 1c.c. injected	1/128	4 p.m. 5-10-32	47·25	Neg.
20-8-32 Patient having hectic fever and passing pus per vaginum. Bleeding profusely now and again. Rusty sputum, no definite signs in the lungs. 3-9-32 Xray of chest showed secondary deposits in the lungs. 4-9-32 bleeding profusely—plugged. Coughed up a clot of blood size of a hen's egg. No tubercle	G84	50	1425	4·5	Nil.	Do.	1	1 c.c. of 2 in 54	1/27	2-45 p.m. 8-10-32	47	Pos.

Serial No.	PATIENT.	Experiment No.	ANIMAL.				Substance injected.	INJECTIONS.			LAPARATOMY.			REMARKS.
			Serial No.	Wt. in grms.	Age in months.	Previous Laparatomies.		No.	Amt. at 1 injec. in c.c.	Total Amount.	Time and date.	Hrs. after 1st injec.	Result	
	bacilli in the sputum. 6-9-32 crepitations in both the lungs. Temperature continuous. 10-9-32 tissue removed from the uterus by ovum forceps. Sent for pathologic report. Pathological Reports: coughed up material does not show any chorionic tissue. The growth (material from the uterus) shows the characters of *chorionic* epithelioma. 16-9-32 blood: white cells 6100. Polymorphs 85%. Lymphocytes 13·5%. Large mononuclears 1·5% R. B. C. 1,760,000; poikilocytes, anisocytes, polychromasia,													

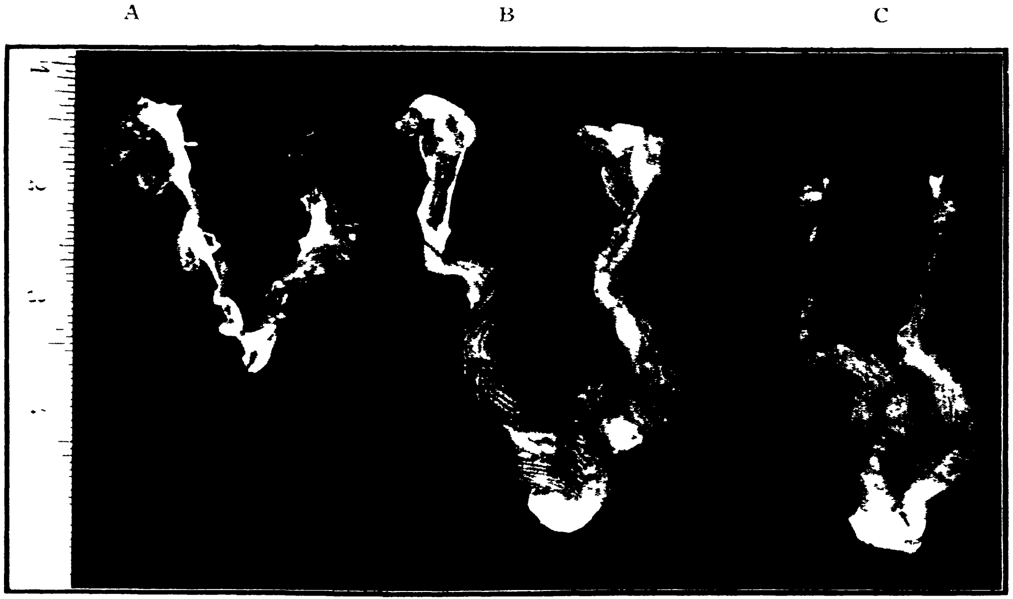
	few normoblasts. No malarial parasites.											
8	Mrs. P. M. K., age 18, para 1. 3 months' amenorrhoea followed by bleeding for the last fortnight. Fundal height upto umbilicus. Foetal parts not felt. 2-45 p. m. 24-10-32 : 2 lauinaria tents introduced 5-20 p.m. 25th October 1932 contents of the uterus digitally separated and removed under anaesthesia. *Vesicular mole* discharged on the 8th day of the puerperium which was uneventful.	G93	29	1690	...	18-7-32 + 13-8-32 + Left ovary removed 29-9-32 +	Catheter passed 12 noon 25-10-32	1	3	3	4 p.m. 26-10-32	24	Pos.
		G96	43	1795	...	31-8-32 4-10-32	Do	1	1	1	4-30 p.m. 3-11-32	47	Pos.
		G98	40	1857	...	21-7-32 16-9-32 +	Do	1	1 c.c. of 2 c.c. in 8	¼	4-30 p.m. 7-11-32	49·5	Pos.
		G100	30	...	...	21-7-32 — 18-8-32 + Left ovary removed 26-9-32 +	Do.	1	1 c.c. of 2 in 16	⅛	3-30 p.m. 9-11-32	46	Pos.

Serial No.	PATIENT.	Experiment No.	ANIMAL.				Substance injected.	INJECTION.			LAPARATOMY.			REMARKS.
			Serial No.	Wt in grms.	Age in months.	Previous Laparatomies.		No.	Amt. at 1 injection in c.c.	Total Amount.	Time and date.	Hrs. after 1st injec.	Result	
		G104	57	1372	...	Nil	Catheter passed 12 noon 25-10-32	1	1 c.c. of 2 in 32	1/16	4-30 p.m. 16-11-32	47	Pos.	
		G106	56	1215	...	Nil	Do.	1	1 c.c. of 2 in 64	1/32	4-30 p.m. 21-11-32	54·5	Pos.	
		G110	48	1300	4·25	13-9-32 — 25-10-32 +	Do.	1	1 c.c. of 2 in 128	1/64	4 p.m. 28-11-32	56	Neg.	
		G94	51	1955	7 Virgin	Nil	Fluid from vesicles	1	4	4				Both produced the typical changes in the ovaries.
		G95	52	...	6·25 Virgin	Nil	Tissue from mole implanted into right thigh							
9	Mrs. S., age 29, 4th para, 3 children living. 2 months' amenorrhoea followed by irregular bleeding for two months. Fundus upto the	G97	26	1835	...	8-7-32 + 3-8-32 — 2-9-32 + 5-10-32 +	1st morning urine of 3-11-32	1	1	1	2 p.m. 5-11-32	45	Pos.	

umbilicus. No foetal parts no foetal heart. Vagina plugged. Mole expelled entire on 19-11-32.	G99	50	1562	5·5	8-10-32 +	1st morning urine of 6-11-32	1	1 c.c. of 2 in 8	¼	3 p.m. 8-11-32	50·75	Pos.
	G101	60	2175	8·25	Nil	Do.	1	1 c.c. of 2 in 16	⅛	3 p.m. 11-11-32	46·5	Pos.
	G103	19	...	...	28-5-32 + 26-6-32 — 20-7-32 — 8-8-32 + 28-9-32 — 22-10-32 —	Do.	1	1 c.c. of 2 in 32	1/16	4-30 p.m. 15-11-32	52	Pos.
	G105	54	1340	...	Nil	Do.	1	1 c.c. of 2 in 64	1/32	4-30 p.m. 18-11-32	48	Pos.
	G112	43	1825	...	31-8-32 — 4-10-32 — 3-11-32 +	Do.	1	1 c.c. of 2 in 128	1/64	3-30 p.m. 2-12-32	49	Pos.

Serial No.	PATIENT.	Experiment No.	ANIMAL.				Substance injected.	INJECTIONS.			LAPARATOMY.			REMARKS.
			Serial No.	Wt. in grms.	Age in months.	Previous Laparatomies.		No.	Amt. at 1 injection in c. c.	Total amount.	Time and date.	Hrs. after 1st injec.	Result.	
		G113	40	1920	...	21-7-32 + 16-9-32 + 7-11-32 +	1st morning urine of 6-11-32	1	1 c.c. of 2 in 256	1/128	4-15 p.m. 5-12-32	55	Neg.	
		G107	53	1305	...	Nil	Fluid from vesicles at 10-30 a.m. on 20-11-32	1	4	4	5 p.m. 25-11-32	126·5	Pos.	
		G108	59	...	...	Nil	3·8 to 3·9 grms. of tissue from a mole implanted into adductor muscles of the thigh at 11-15 a.m. on 20-11-32	...	...	...	10 a.m. 27-11-32	166·75	Pos.	

PLATE I



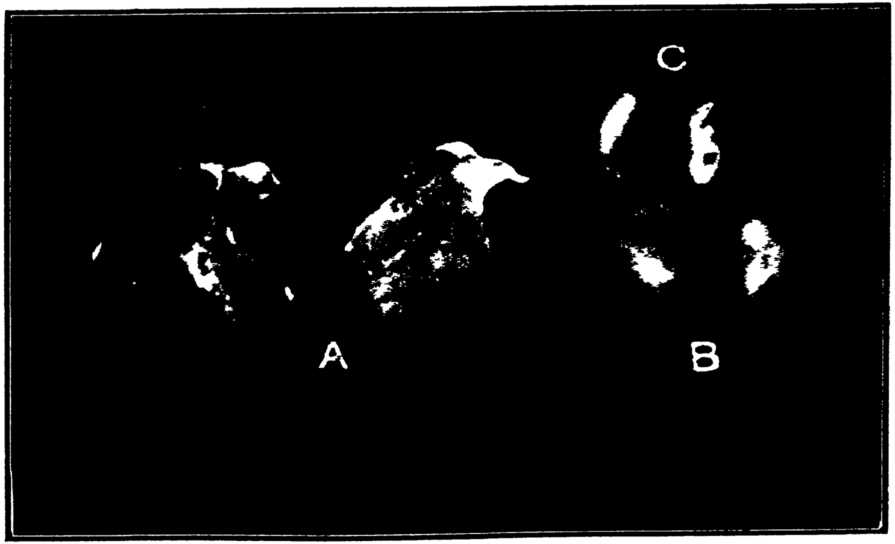
Uterus, Tubes and Ovaries of Rabbits
Positive reaction in an immature animal

(A) Expt. G. S. M. C. VIII, animal H. 559,2·5 months injected with the urine of an eight months pregnant patient

(B) Positive reaction in a mature animal.
Expt Haft. 9, an isolated mature animal injected with the urine of an eight months pregnant patient.

(C) Negative Reaction.

PLATE II

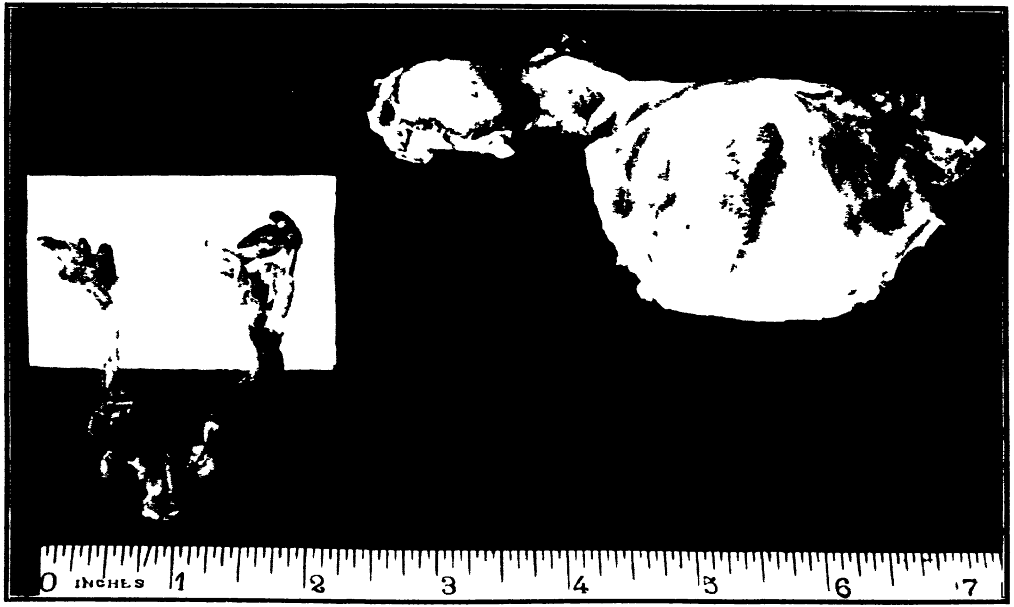


Ovaries of Rabbits (slightly enlarged)

A & B are the same as plate I
(C) Negative Reaction.

An isolated mature animal injected with the urine of a patient, 10 days over her period; pregnancy? The ovary on the right shows 3 enlarged Graffian Follicles They are clear and flat topped. They have been specially rendered prominent on account of the difficulty of depicting them in a photograph like this. This should not be mistaken for any sign of haemorrhage into them.

PLATE III

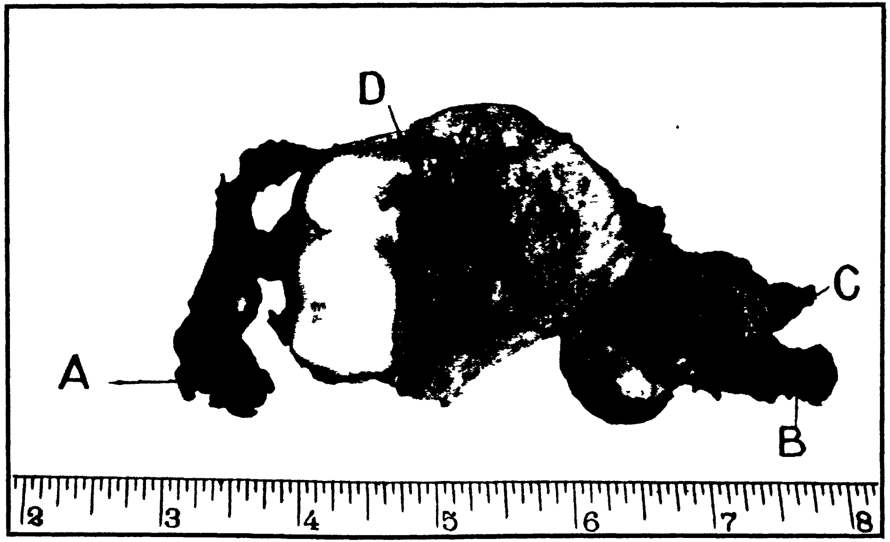


Expt Haff 20 Ectopic Gestation Table VIII, Case II

The uterus and the rt tube Blood clot seen through the abdominal ostium of the tube, the ampullary end of which is definitely enlarged Sections revealed the presence of chorionic villi

The lower photograph shows the genital tract of a virgin rabbit 3. 75 months old injected with the first post operative specimen, of the patient's urine Each ovary shows 3 haem spots

PLATE IV



Chorionepithelioma of the uterus.

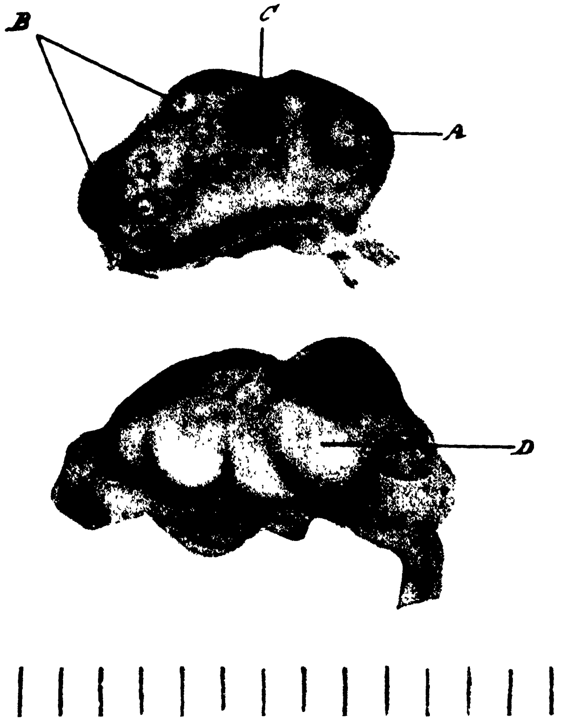
Table X case 6.

A & B. Abdominal ostia of the tubes.

C Accessory abdominal ostium.

D. The growth itself.

PLATE V



Ovaries of Rabbits (one division = 1/16 inch)

Upper ovary – from rabbit SXXV, weight 1567 grams, 52 hours after an injection of 1·1 c.c. of the urine of a case of chorionepithelioma (Table X case 7, experiment G 79).

Lower ovary—from rabbit SXLIV, weight 1600 grams, 43·5 hours after the first injection—total amount being 12 c.c.—of urine of a patient who expelled a vesicular mole 8 days before the test (Table X—case 5)

A=ripe graffian follicle.

B=freshly ruptured follicle.

C=a typical corpus haemorrhagicum.

D=one of the luteinized graffian follicles.

SOME CHARACTERISTICS OF THE INDIAN PELVIS

By

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The treatment of 'Disproportion' in various countries is likely to be in a nebulous state until the characteristics of the pelvis and foetus of various nations and races are carefully studied. Every nation or race has its peculiarities of height, size and shape, which must necessarily affect the development of the pelvis. It is no wonder, therefore, that a particular treatment of disproportion should give very best results in the hands of an English or American Obstetrician and fail in the hands of a Chinese, Japanese or Indian Obstetrician. The principle laid down for a "Trial Labour" or any other treatment of disproportion is based on the average size of the pelvis and foetus which, if compared, with the Indian (Bombay) pelvis and foetus will, I presume, be found much larger.

Very little work has been done towards comparing the pelvis, the foetus and the labours of European and Indian women. Referring to the literature, one finds reference here and there to remarkably easy labours among aboriginal peoples. Some writers mention certain racial differences and state that the pelvis of the less civilised races is narrow and deep as compared with the low and broad pelvis of the European. Reference is often made by some writers and specially by Schartan and Wornich, to the increased difficulty of labour when native women of Africa are impregnated by Europeans.

Though we find some observations of Wornich comparing the heads of Europeans and Japanese children, as well as by Lane based upon the comparison of a few Europeans, Eurasians (Anglo-Indians) and Bengalis, comparatively little is known of the relative measurements of the pelvis and the foetal head in various races in India (Bombay).

With the purpose of studying the differences between the European and the Indian races, and with the hope of finding something definite regarding the size, shape of the pelvis and the development of the Indian pelvis and Foetus, I conducted an inquiry into the causation of foetal and maternal Dystocia in India (Bombay), under the auspices of The Indian Research Fund Association, at the G. S, Medical College, from December 1929 to February 1932,

Material.—Our material was obtained from the records, ante-natal clinics, pre-natal, natal, post-natal, Gynaecological and other wards of the K. E. M. Hospital, The N. W. Maternity Hospital and the Bai Motlibai Hospital.

Method.—The questionnaire was based upon routine history giving the pelvic measurements and other data concerning the mother, labour foetus. Vide Appendix No 1.

From December 1929 to February 1932, 8,714 pelvis, 566 abnormal labours and 4,573 foetuses have been investigated. Our work has been chiefly among the Deccani Hindus (upper and lower classes), Gujarati Hindus, Mohamedans and Indian Christians. In these communities the average measurements were as follows:

TABLE No. 1

Average external Diameters.

	Interspinous	Intercrestal	External Conj.
European (Text books)	*26·5 cms.*	*28 to 29 cms.*	*20 cms.*
Indian Group 1	18 to 20	20 to 22	15 to 17
Indian Group 2	20	22·5	17
Indian Group 3	22·5	25	17·5

Group 1 was met with in the Deccani Hindus of lower class.
Group 2 was met with in the Daccani Hindus and Gujratis in general.

Group 3 was met with in the higher class Hindus, Mohamedans and Indian Christians.

The following Table shows the frequency of the groups among the Deccani Hindus of upper class (A) and lower class (B).

TABLE No. 2

	Hindus A	Hindus B
Group 1	3 %	6 %
Group 2	27 %	38 %
Group 3	63 %	49 %

In a series of 1,922 labours the presentations were as follows:

TABLE No. 3

Spontaneous Labour		Pathological Labour	
Vertex Anterior	1546...92·4%	Vertex Anterior	194...78·2%
Vertex Post.	47... 2·8%	Vertex Post.	18... 7·3%
Breech Ant.	64... 3·8%	Breech Ant.	6... 2·4%
Breech Post	2... 0·1%	Breech Post.	......
Face	13... 0·8%	Face	3... 1·2%
Brow	2... 0·1%	Brow	......
		Shoulder	27...10·9%
	1674...100		248...100

The relation of the external to the internal pelvic measurements was also ascertained at the operation table, post-mortem and dissection rooms in every available case. Table No. 4 shows the measurements of one of the groups of 29 consecutive cases for comparison.

TABLE No. 4

EXTERNAL PELVIC MEASUREMENTS. | INTERNAL PELVIC MEASUREMENTS.

No.	Caste.	Int. Sp.	Int. Crs.	Ext. Conj.	Trans V.	Obliq.	True Conj.
	European "Text Books."	*26·5*	*28-29*	*20*	*13*	*12·5*	*11*
1	Mohd. ...	22·5	25	18	12cm.	12·5	10·5
2	Hindu A ...	21	23	17	11·75	11·75	10
3	Gujti. A ...	21·5	25	17	12	12·5	9·5
4	Goan ...	25	27·5	18	12·5	12	11
5	Hindu B ...	20	24	18·5	12·5	12	11
6	Goan ...	20	24	17·5	11	12	11
7	Goan ...	21·5	25	18·5	13	12	10
8	Goan ...	23	25	19	11·75	12·5	11
9	Goan ...	18	21	16	10·5	10·5	10·5
10	Hindu B ...	21	23	17·5	12·5	12·5	10
11	Hindu A ...	22	25	17	12	12·75	10
12	Hindu B ...	23	25·5	18·5	12·5	12·75	10
13	Hindu B ...	22	25	17	12·5	12·5	10·5
14	Hindu B ...	24	24	17	12	12·5	10·5
15	Hindu B ...	20	21·5	17	11	12·5	10

EXTERNAL PELVIC MEASUREMENTS.					INTERNAL PELVIC MEASUREMENTS.		
No.	Caste.	Int. Sp.	Int. Crs.	Ext. Conj.	Trans V.	Obliq.	True Conj.
16	Hindu B ...	21	26	18	12	12·5	11
17	Hindu B ...	22	24	17	12	12·75	10
18	Hindu B ...	22	24	17	11	12·5	9·5
19	Hindu B ...	22·5	25	17·5	12	12·75	10
20	Hindu B ...	22	24	17·5	11·5	12·25	10
21	Goan ...	22·5	25	17·5	12·5	13	10
22	Hindu ...	21	24	17·5	11·5	12·5	10·5
23	Parsee ...	22	24	17	12·5	13	10
24	Hindu B ...	21·5	23	17	11·5	12·25	11
25	M. Purdha ...	21	24	17	12	12·5	11
26	Goan ...	23	25	17·5	12·25	12·25	10·5
27	Hindu B ...	22	24	17·5	12·5	12	11
28	Mohd. ...	22·5	24	18	12·5	12·25	11
29	Mohd. ...	23	25	17·5	11·5	12·5	10·5

In a group of 163 spontaneous labours collected from among the Hindus (lower class) the external conjugate varied from 15 to 16 cms. and their past obstetric history was uneventful.

If we turn back to Tables Nos. 1 and 4 and compare the Indian measurements with the European, we soon see the difference in the two pelvises. The external diameters in the European pelvis are larger than those in the Indian pelvis, but the relation of the external diameters to the internal diameters in the two pelvises differ. In the Indian pelvis the external diameters are smaller, but there is relatively less alteration in the size of the internal diameters. Then again the relation of the three internal diameters also differs in the two pelvises. The transverse diameter in the European pelvis is longer by about 1 cm., but the length of the oblique diameter is practically the same in both. The external diameters of the Indian pelvis therefore gives no certain criterion of the internal diameters of the true pelvis and it is no wonder that a patient with an external conjugate of 15 to 16 cms., labeled for "Caesarian", should have spontaneous labour while awaiting the arrival of the Surgeon for the operation.

During the course of my investigation, I have come across several primiparas admitted to the Hospital, in labour, with the foetal head floating above the brim. Most of these women were under 20 years of age, poorly developed and of short stature. These type of women commonly have a small abdomen. The uterus is small and somewhat narrow and is often deviated to the right and almost under the costal arch. The external measurements of the pelvis are small and the external conjugate is often between 15 and 16 cms. The head is prominent above the brim. I have followed the mechanism of labour in 120 cases of this type of women, and all of them had spontaneous labour, except 6, in whom Forceps had to be applied for rigidity of the soft parts. In these cases the descent of the head is prevented by the uterine tissue, and the parametrium surrounding it, and there is no actual disproportion between the head and the pelvis when the soft tissues are removed: nor is there any appreciable change in the relation of the head to the pelvis during labour until the soft tissues have been removed by dilatation.

I am inclined to believe that in this type of cases there is some developmental fault in the uterus. Either the uterus is not fully developed, cockliate or malformed and is, therefore, placed in the pelvis at a higher level than the normal uterus. These are the type of patients that are often times at the ante-natal clinic given red card indicating disproportion and suggesting a Caesarian Section or Pubiotomy.

Conclusions

From the findings in our series of cases it would seem justifiable to draw the following conclusions:

(1) That the Indian pelvis is *Round* as compared with the European *Oval* pelvis.

(2) That the external diameters of the Indian Pelvis give no certain criterion of the internal diameters of the true pelvis.

(3) That *Spontaneous Labour* may be expected in the Indian pelvis with an external conjugate of *15* to *16* cms.

(4) That the *Indian Foetus* is relatively smaller. The cranial bones are softer and mould easily.

(5) That a Trial Labour, judiciously advocated, will spare many Indian Women from serious operations and their consequences.

(6) That the information obtainable by our students from the current text books on Midwifery, on the Anatomy of the pelvis, is only applicable to the Indian pelvis with some reservations, specially with regard to its size and shape. Therefore it is but meet that students in India be taught *Midwifery* according to the *requirements* of the *INDIAN PELVIS.*

APPENDIX I

Seth Gordhandas Sunderdas Medical College.

MATERNAL & FOETAL DYSTOCIA-INQUIRY IN BOMBAY

The Mother

Serial No. *7* Hospital { Name *Bai Motlabai* Register No. *673* } Date *18-7-31*

Name *Z. H.*

Address *Agripada Police Station.*

Duration of residence in Bombay *Life long.*

Caste *Mohomedan* Occupation *House-wife* Purdah *No.* Housing *poor* Diet *Mixed.*

Age *25* Para *III.*

Menstrual history *Began at 14 Cycle 5/28 Dismenorrhroea-prementstraicl pain for 3 days-during the periods for 2 days.*

Age at Marriage *16* Age at Cohabitation *16.*

Previous General Health *Fair.*

Past obstetric history *1st Miscarriage at 5 Months 8 years ago. 2nd Child 2½ years died 13 days after birth.*

Pelvimetry In. Sp. *22* In. Crest *24* Ext. Cong. *17* Obst. Cong...... Transverse of the outlet *9* P. I. S. *9·5.*

Oblique of the Brim......... Trans. of the Brim......... True. Conj..........

Pelvic joints *pain in the Sacro Illiac* Deformities *nil* Height of the Pt. *55"* weight.......

X-Ray Photo *1285 Serial 52* Photograph *No.*

Present Obstetric History *Pain the Rt. hip joint and Sacro Illiac joint for the past 2 months ? Osteomalachia Pt. had a fall 20 days after the Miscarriage and since then has pain in the joint.*

Duration of gestation *F. T.* Labour began at *9 p. m. 22-7-31.*

The attitude of the foetus *Full Flexion* Presentation *Vertex* Position *I.*

General foetal conditions *Head floating Sacrum Curved exaggerated from above downwards left Illiac fossa lifted upwards Head ballotable at the fundus, foetal heart to the Rt. and above the level of the umbelicus.*

The Forces.................................

The Passages *Deformed—Osteomalachia.*

(Obstruction if any)............................

General Maternal Conditions...................

Duration of Labour......... 1st Stage......... 2nd Stage......... 3rd Stage..........

Termination of Labour Spontaneous......... Artifical *Caesarian Section 11-30 p. m. 22-7-31.*

The Foetus.

Weight *?*

Development *F. T.*

....

Length *18½"*

C. Measurements *12½"* *S.O.B. 9.*

.... *13* *O. F. 10.*

.... *B. P. 9.*

.... *B. T. 8.*

Moulding *Nil.*

Malformations *Nil.*

Remarks.

APPENDIX II (TABLE I).

Total number of cases investigated till 16th Sept. 1930, commencing from 10th Dec. 1929.=4,229.

—	Hindus.				Mohmedans.		Christians.					Parsi	Irani	Jew	Sikh
	Deccani.	Gujarati.	Bengali.	Madrasi.	Purda.	Non-Purda.	Goanese.	East Ind.	Ind. Chris.	Manglorian.	Anglo Ind.				
	2,416	482	6	53	94	256	443	179	98	48	59	58	6	22	9
Average height of Pt. (in inches) ...	57"	56·7"	55·5"	55·7"	56·9"	57"	58·6"	58·6"	58·5"	59"	59"	59"	59·5"	57"	57"
* ,, weight ,, (in lbs.) ...	85	96	...	84·4	93	96·5	91	96·8	93·3	96·2	96·8	100	100·3	92	85
,, Pelvic measurements.															
(*a*) Inter Spinous (cm.)	21·75	21·65	21·65	21·49	21·12	22	22·25	22·25	22	22·10	23	22·50	22·50	22	22·25
(*b*) Inter cristal ,, ...	24	24	24·25	23·25	23·50	24·25	24·32	24·50	24·25	24·50	25·25	24·60	24·75	24·50	25
(*c*) External Conjugate (cm.) ...	17	16·25	17·50	16·75	16·47	17·17	17·25	17·50	16·75	17·25	17·50	17·50	18·12	17·20	17·75
(*d*) Anatomical ,, ,, ...	9·8	9·5	10	9·6	9·33	9·64	10	9·9	9·8	10	10	10	10	9·8	10
(*e*) Transverse of the outlet. ...	9·7	9·8	9·7	9·3	9·3	9·7	9·9	9·9	9·7	10	10	9·92	10	9·7	9·9

* The Average wt. recorded is of the non-pregnant women only.

N. B.—Averages of communities, numerically few, are given for the sake of comparison only.

TABLE No. II

Total number of spontaneous Labour Cases=2,166.

	Hindus.				Mohmedans.		Christians.					Parsi	Irani	Jew	Sikh	Total.
	Dec-cani.	Guja-rati.	Ben-gali.	Mad-rasi.	Pur-da.	Non-Purda	Goa-nese.	East Ind.	Ind. Chris.	Mang-lorian.	Anglo Ind.					
1 Para: (*a*) Primipara ...	330	56	2	11	1	30	43	22	10	5	11	4	1	2	...	528
(*b*) Multipara ...	1,074	190	1	22	4	65	107	82	35	14	28	9	...	2	5	1,638
2 Presentation.																
(A) Cephalic: Antr. ...	1,292	232	3	32	5	86	139	98	40	19	32	10	1	4	5	1,998
Post. ...	61	5	...	...	...	7	6	3	1	...	4	1	...	...	...	88
(B) Podalic: Anter. ...	49	9	...	1	...	1	5	3	4	...	2	2	...	...	...	76
Post. ...	2	...	...	...	...	1	...	...	...	...	1	...	...	...	...	4
3 Spontaneous Births.																
(A) Live Birth	1,295	231	3	30	5	85	142	95	40	18	39	13	1	4	5	2,006
(B) Still Birth	109	15	...	3	...	10	8	9	5	1	...	...	...	...	...	160

N. B.—This Table does not include cases of multiple births or cases of live and still births in presentations other than cephalic and podalic of the foetus.

TABLE No. III.

Total number of Foetuses=2,315.

	Hindus.				Mohmedans.		Christians.					Parsi	Irani	Jew	Sikh.
	Dec-cani.	Guja-rati.	Ben-gali.	Mad-rasi.	Purda.	Non-purda.	Goa-nese.	East Ind.	Ind. Chris.	Mang-lorian.	Anglo Ind.				
	1,533	233	3	26	15	87	178	98	47	22	40	18	2	7	6
Measurements.															
(*a*) Length (in inch)...	18·61	18·36	18·5	18·5	18·41	18·40	18·33	18·51	18·45	19·6	19	19	19·8	19	19·5
(*b*) Weight (in lbs.)	5·88	5·44	6	5·5	5·37	5·86	6·21	6·34	5·75	6·6	7·3	6·7	6·75	6·5	6
(*c*) Cephalic circumference (in cm.)															
i. Sub-occipito Bregmatic ...	31·00	29·75	31·25	30·75	29·10	30·10	31·07	30·47	30·47	30·50	32·65	33·25	33·75	31·92	31·25
ii. Occipito Frontal	32·62	31·25	32·25	32·00	32·80	33·67	33·9	30·45	39·92	33·00	34·5	34·25	36·2	33·75	32·50
(*d*) Cephalic Diameter (in cm.)															
i. Sub-occipito Bregmatic ...	8·7	8·5	...	8·75	9	8·62	8·75	8·52	8·97	8·75	8·55	8·75	10	8·5	...
ii. Occipito Frontal	10·67	10·30	...	10	10	10·35	10	10·40	10·67	10·40	10·45	10·50	11·25	11·25	...
iii. Biparietal	8·25	8·25	...	8·75	7·40	7·85	8·15	8·12	8·27	8·35	8·12	8·25	9·92	8·12	...
iv. Bitemporal	6·25	6·25	...	6·25	6·75	7·07	6·25	6·87	6·70	6·80	7·5	6·25	8·12	6·25	...

N. B.—This Table includes cases from records, of fœtuses of abnormal labour cases and fœtuses from cases in which maternal data were not available.

Obstructed and Delayed Labour Cases = Total 237

———	Hindus.				Mohme-dans.		Christans.									
	Deccani.	Gujerati.	Bengalee.	Madrasi.	Purdah.	Non-Purda.	Goan.	East Indian.	Indian Chr.	Manglo.	Anglo Indian	Parsi.	Irani.	Jew.	Sikh.	Total.
TOTAL: Primipara	69	3	1			9	7	5	3	1	3	3	1	1	1	107
Multipara	101	1		2	1	8	6	4	4	1	1			1		130
DYSTOCIA: (A) Foetal																
1 Bregma																
2 Brow	3															3
3 Face	10	1					1				1					13
4 Nœgale's Obliquity						1										1
5 Litzmann's Obliquity																
6 Prolapse of arm	21	2				1			1							25
7 „ of cord	14					1	1	2	1							19
8 ,, of leg	3	1														4
9 Pelvic Presentation																
10 Shoulder ,,	34			1			1		1							37
11 Multiple Births	25	6				2	1	1	1		1	2				39
12 Compound Presentation	4	1														5
13 Long cord	5	3														8
14 Short cord	5	6														11
15 Malformation	8	2		2		1	1				2	1		1		18
(B) Maternal																
1 Inertia: Abdominal	4	2														6
: Uterine	42	6		1		4	3	1	2	2	1	1		1		64
2 Anomalies of Membrane	23	2			1	3	2	5	3	1		1		1		42
3 Rigidity of the Os.	7	1				1					1					10
4 Trismus Uteri	4															4
5 Malposition of the Os.		1					1									2
6 Rigd. or Atrasia of vagina	37	1	1			2	7	4	1	1		1	1	1	1	58
7 Diastasis of Pelvic joints	2	1														3
8 Pelvic contration	31	1			1	6		2			2					43
9 Pelvic Deformity	3					2										5
10 Elderly primipara	26	2		1		2	3	1	2	1	5	1	1		1	46
11 Termination of Lab.																
a Spontaneous	13	1					1				1					16
b Version	53			1		3	3	4	4	1						69
c Forceps	65	3	1	1		7	8	4	3	1		2	1	2		98
d Craniotomy	17	1				2	1				1	1				23
e Cœsarian Section	22				1	6		1								30

STUDIES IN THE BIOPHYSICS AND BIOCHEMISTRY OF BLOOD IN TUBERCULOSIS.

By

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The following is a brief summary of work done at the Physiology School, Grant Medical College, Bombay, under the above Research Fellowship. The clinical material was mostly obtained from the Sir J. J. Hospital, Bombay.

These "studies" comprised the following topics in relation to Pulmonary Tuberculosis:

I. Suspension Stability of the Blood.
II. Blood Pressure.
III. Blood Calcium.
IV. Blood Sugar, Blood Urea, and Blood Chlorides.

I. SUSPENSION STABILITY OF BLOOD.

The stability of a fluid to keep in suspension any given substance or element can be said to depend upon its capacity to resist the natural tendency of that element to settle down in the form of a sediment. The rate of sedimentation of that element can therefore be taken as a reasonable index of the suspension stability of that fluid. In blood the suspension stability can be gauged by noting the sedimentation rate of the red blood corpuscles. A clear observation of the sedimentation, however, is possible only if the blood is prevented from clotting by the addition of some anticoagulant. Hence the whole test resolves itself into what is known as the "sedimentation test."

Although the phenomenon of sedimentation was known to some extent even in the days of Hippocrates and Galen, it was first taken advantage of and put to clinical use as a laboratory test by Fahreus in 1917 in gynaecological and obstetrical cases. Since then it has been used in relation to various other diseases also by different workers all over the world using different methods almost all of which require the use of some sort of special pipette which, as far as I know, has not yet been standardised. I therefore used the following simple method in my investigations.

Venous blood obtained with due aseptic precautions from the bend of the elbow and prevented from clotting by the addition of a

3·8 per cent. sodium citrate solution in the proportion of 1 to 4 of blood was sucked upto the zero mark and made to stand vertically in a one c. c. ordinary serological pipette graduated into hundredths as shown in the figure (Fig. 1). A bullet of plasticine (or soft paraffin) at the lower end of the pipette prevented the blood from escaping out. The sedimentation of the red blood corpuscles was observed every ten minutes for two hours and the divisions of the pipette travelled noted at each interval. The figures were then plotted on graph paper in each case with the time (in minutes) as the abscissae and the divisions of the pipette as the ordinates. The demarcation between the red cell column and the supernatent plasma was remarkably sharp in every case.

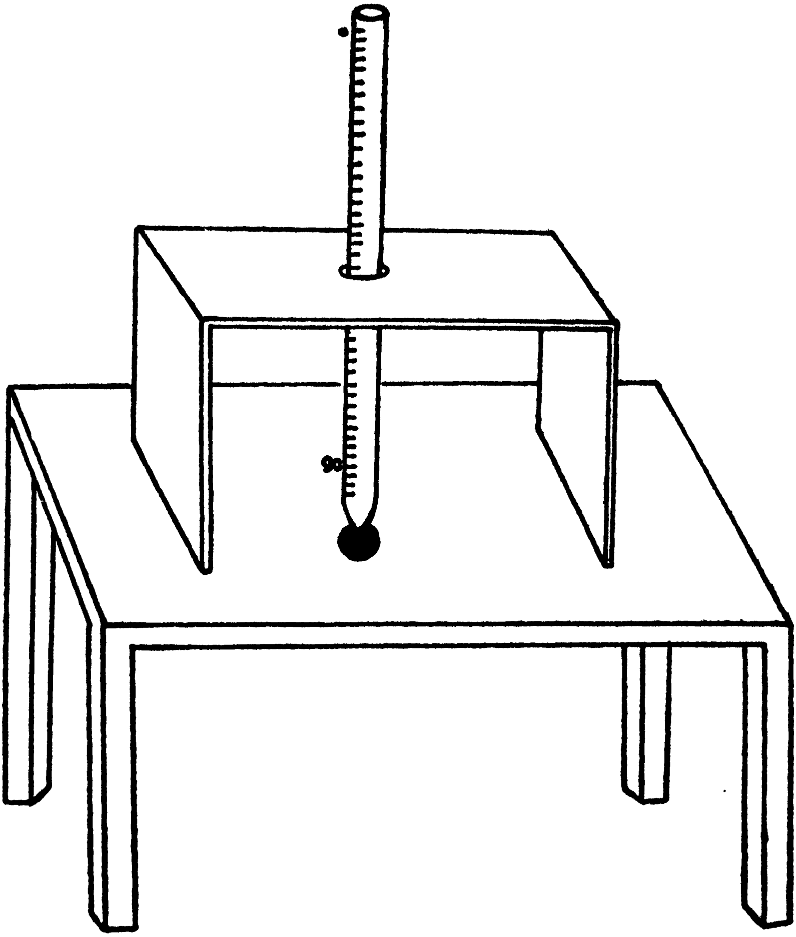

FIG. 1.—Arrangement of the pipette for the sedimentation test.

The following observations were recorded :—

1. Sedimentation rate of R. B. C. in blood of ten apparently normal individuals. The data obtained are given in the following Table (Table I). The average data plotted on graph paper gave the following curve (Fig. 2).

TABLE I
(*Normal Cases*)

Case No.	TIME IN MINUTES											
	10	20	30	40	50	60	70	80	90	100	110	120
	Divisions of the Pipette											
1	·5	1	1·5	2·5	3·2	4	5·1	6·2	7·1	8	8·9	10
2	·5	1	1·3	1·5	2	2·3	2·9	3·2	3·7	4	4·4	5
3	·2	1	1·7	2·4	3·2	4	5	6	6·8	7·3	8.2	9
4	·2	·5	1·3	2	2·5	3·4	4·1	4·8	5·5	5·9	6·5	7
5	·2	·4	·6	1·1	1·3	1·8	2·1	2·6	3·1	3·5	4	4·5
6	·2	·4	·6	1·2	1·6	2·1	2·5	3·1	3·6	4·2	5	5·5
7	·4	1	1·4	1·9	2·5	3·1	4·1	4·4	4·7	5	5·2	5·4
8	·5	1·3	2	2·8	3·6	4·3	5	5·6	6·1	6·6	6·9	7·1
9	·3	1·1	1·9	2·7	3·4	4·2	4·9	5·5	6·1	6·6	7·1	7·5
10	·6	1·2	1·9	2·7	3·5	4·3	5	5·7	6·4	7·1	7·8	8·4
Average	·36	·89	1·4	2	2·6	3·3	4	4·7	5·3	5·8	6·4	6·9

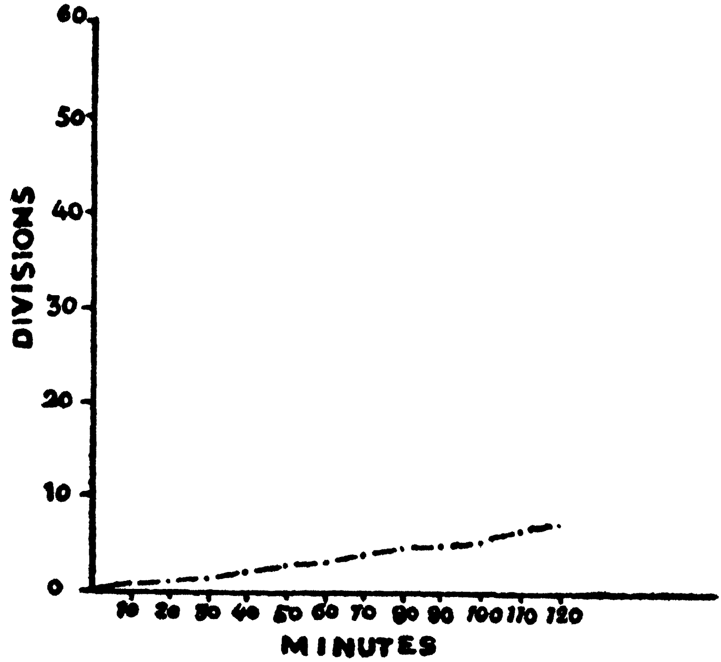

FIG. 2.—Average normal curve. (10 Cases).

2. Sedimentation rate of R. B. C. in the blood of fifty-eight patients suffering from Tuberculosis comprising (*a*) fifty cases of the pulmonary, (*b*) four of bone, (*c*) three of gland, and (*d*) one of intestinal type. The Bone T. B. cases all presented sinuses open to the, exterior.

The following tables indicate the figures obtained. (Tables II III, IV and V respectively.).

TABLE II

(*Pulmonary Tuberculosis Cases*)

Case No.	TIME IN MINUTES											
	10	20	30	40	50	60	70	80	90	100	110	120
	Divisions of the Pipette											
1	6	18	27	33	40	46	52	56	...	...	...	...
2	5	9	18	24	30	35	39	42	45	47	48	50
3	2	6	9	12	15	20	23	26	30	34	37	40
4	9	21	33	43	49	54	58	60	61	61·5	62	62
5	2	5	8	11	14	18	23	27	30	33	35	37
6	9	30	44	55	61	64	65	66	66	66·5	67	67
7	2	7	13	17	23	28	34	37	41	45	48	50
8	3	10	17	25	32	37	41·5	45	48	51	54	56
9	5	18	24	42	50	56	61	64	66	68	69	70
10	2	5	8	11	14	17	20	23	26	29	32	35
11	4	10	23	32	41	48	53	56	59	62	63·5	64
12	2	5	10	17	24	28	33	38	44	48	51	54
13	3	10	17	24	31	36	40	44	48	51	53	55
14	1	4	9	14	19	24	29	34	38	41	43	45
15	1	4	8	12	17	21	25	28	31	33·5	35.5	37
16	2	5	11	19	27	34	39	43	45	46	46·5	47
17	5	14	23	31	37	43	47	49	51	53	54	55
18	1	4	7	10	13	16	19	22	24	26	27	28
19	0	2	3	5	7	9	11	13	15	17	19	21

Case No.	TIME IN MINUTES											
	10	20	30	40	50	60	70	80	90	100	110	120
	Divisions of the Pipette											
20	2	8	14	22	28	32	37	41	44	46	48	49
21	4	8	14	20	27	35	42	48	52	54	56	57
22	2	5	9	13	18	22	26	29	32	34	36	38
23	3	9	16	24	32	37	41	44	47	50	52	53
24	1	4	6	10	15	20	24	28	32	35	37	39
25	3	8	14	21	28	33	37	41	44	46	48	49
26	2	6	12	18	25	30	35	39	43	46	48	49
27	1	3	6	10	15	20	25	29	33	36	38	40
28	2	5	9	13	19	25	31	35	39	42	44	45
29	2	4	8	12	16	20	25	29	32	34	35	36
30	3	7	11	16	21	27	33	38	42	45	47·5	49
31	1	3	6	9	14	20	25	30	34	38	41	43
32	3	8	13	19	25	32	39	43	46	50	53	56
33	1	3	5	8	12	16	20	23	26	28	29	30
34	2	5	9	13	18	23	29	33	36	38	39	40
35	2	5	9	13	18	23	28	32	35	37	38·5	39
36	2	4	7	10	14	17	20	23	25	26·5	27·5	28
37	1	3	7	11	16	21	25	29	32	34	35·5	36
38	2	5	9	13	19	25	30	34	38	41	44	46
39	2	6	10	15	22	30	37	42	46	49	52	54
40	2	4	7	9	11	13	15	18	21	24	26	28
41	3	12	25	33·5	42	50	57	63	68	74	76	77
42	4	7	11	16	22	28	34	40	45	50	54	58
43	2	8	15	22	30	39	46	52	57	62	66	70
44	2	6	10	14	19	24	28	32	36	39	42	44
45	2	5	9	14	21	28	35	41	47	49	51	52
46	1	2	4	6	8	10	11·5	12·5	14	15·5	17	18·5
47	2	3	5	7	10	13	17	21	25	28	31	33
48	2	7	13	22	31	40	48	55	61	65	67	68
49	1	1·5	2·5	5	7	9	12	15	19	22	24	25
50	1	3	5	7	10	13	16	18	20	21	22	23
Average	2·5	7	12	19·5	23	28	32·5	36·5	39·5	42	44	45·5

TABLE III

(Bone Tuberculosis Cases)

Case No.	TIME IN MINUTES											
	10	20	30	40	50	60	70	80	90	100	110	120
	Divisions of the Pipette											
1	3	12	24	34	41	46	49	51·5	53·5	55	56	57
2	2	6	10	14	19	24	29	34	38	41	43	45
3	1	3	7	12	17	22	28	34	39	43	47	51
4	2	4	7	10	14	18	22	25	28	30	31	32
Average	2	6	12	17·5	22·5	27·5	32	36	39·5	42	44	46

TABLE IV

(Gland Tuberculosis Cases)

Case No.	TIME IN MINUTES											
	10	20	30	40	50	60	70	80	90	100	110	120
	Divisions of the Pipette											
1	1	3	5·8	9	13	17	20	23	25	27	29	31
2	1	2	4	6	8	11	14	17	21	23	25	26
3	·5	1	2·5	4	6	9	12	16	20	23	25	27
Average	1	2	4	6	9	12	15	19	22	24	26	28

TABLE V

(Intestinal Tuberculosis Case)

Case No.	TIME IN MINUTES											
	10	20	30	40	50	60	70	80	90	100	110	120
	Divisions of the Pipette											
1	1·5	3	6	9	11	14	17	20	23	26	30	35

The average data in each type plotted on graph paper gave the following curves (Fig. 3).

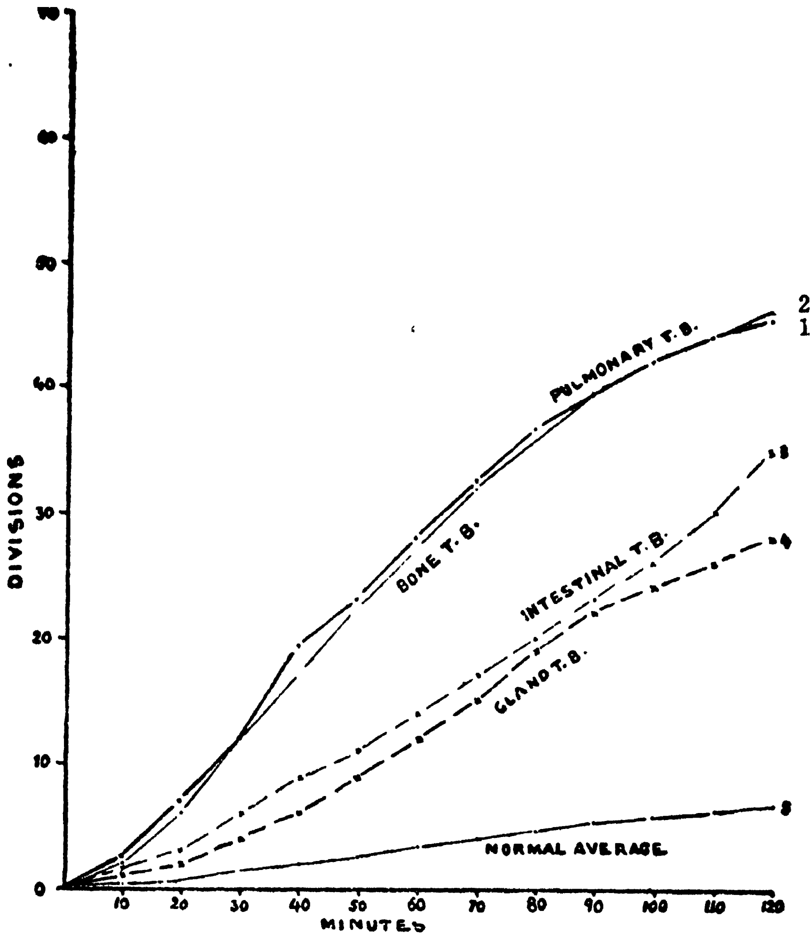

FIG. 3—Average curves of four types of tuberculosis compared with the average normal. 1. Pulmonary Tuberculosis (50 cases); 2. Bone Tuberculosis (4 cases); 3. Intestinal Tuberculosis (1 case). 4. Gland Tuberculosis (3 cases). 5. Average normal.

The average curve of all the four types together (58 cases in all) is shown in Fig. 4 which also compares it with the average curve of each type separately as also with the average normal.

Figs. 5 and 6 compare the lowest tubercular curve with the average and the highest normal curve respectively.

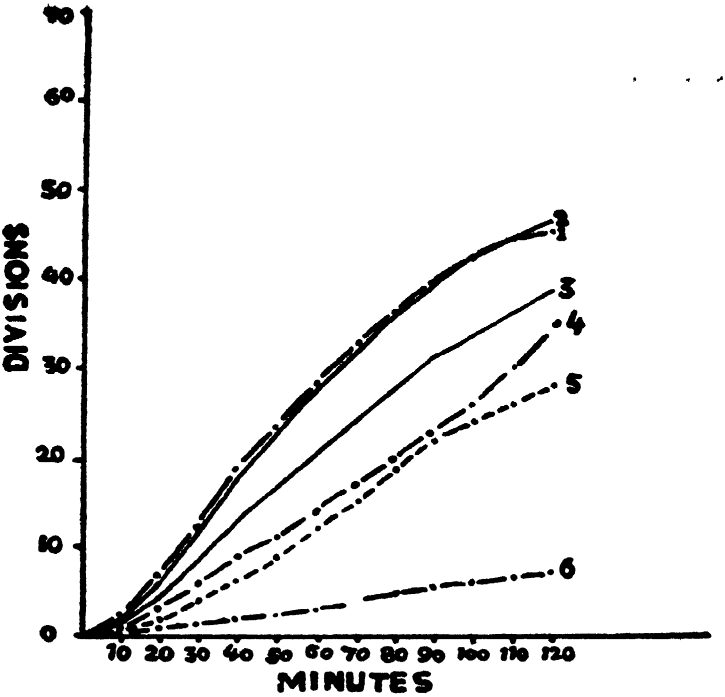

FIG. 4.—Average curve of all the four types of Tuberculosis taken together compared with the average curve of each separately and also with the average normal curve. 1. Pulmonary Tuberculosis (50 cases); 2. Bone Tuberculosis (4 cases); 3. Average tubercular curve (58 cases); 4. Intestinal Tuberculosis (1 case); 5. Gland Tuberculosis (3 cases); 6. Average normal.

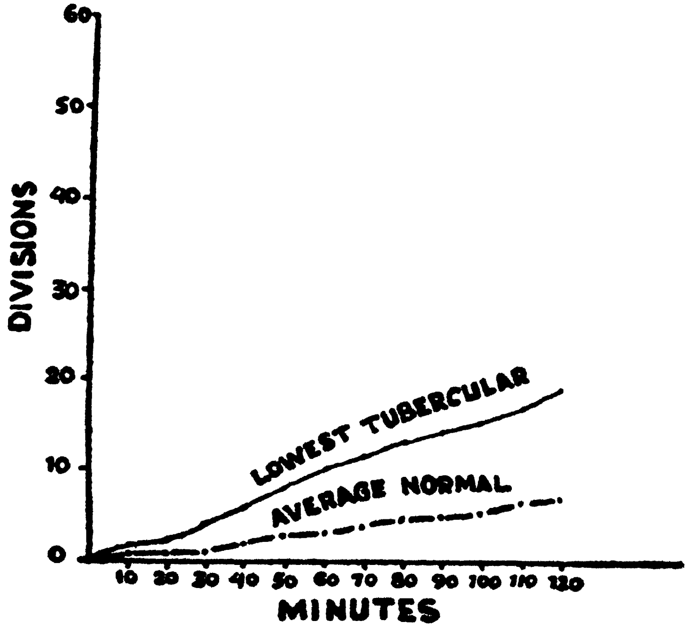

FIG. 5.—Lowest tubercular curve (58 cases) compared with the average normal (10 cases).

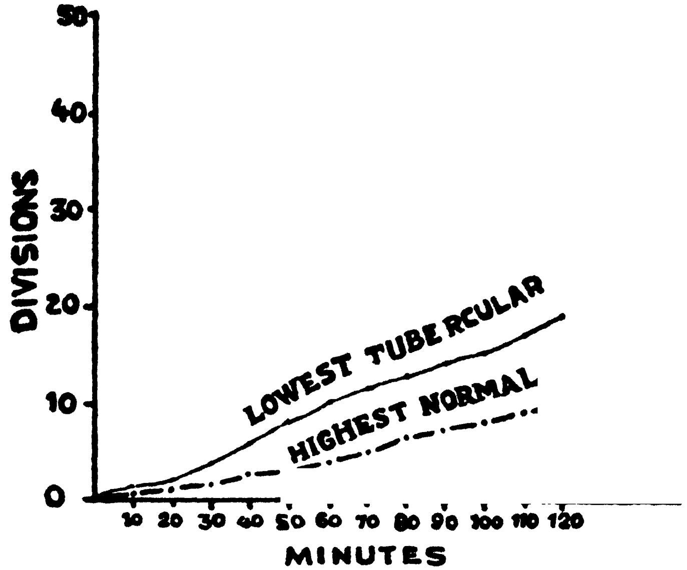

FIG. 6.—Lowest tubercular curve compared with the highest normal.

3. Sedimentation rate of R. B. C. in the blood of:

(*a*) six patients suffering from Lobar Pneumonia,
(*b*) two „ „ „ Amœbic Dysentery,
(*c*) six „ „ „ Malaria,
and (*d*) two „ „ „ Osteomyelitis,

all during their acute stages. These were observed for purposes of comparison in differential diagnosis. The figures are given in Tables VI, VII, VIII and IX. Curves obtained by plotting the average data in each condition are shown in Fig. 7 which compares them at a glance with the others mentioned above.

TABLE VI

(*Lobar Pneumonia Cases*).

Case No.	Time in Minutes											
	10	20	30	40	50	60	70	80	90	100	110	120
	Divisions of the Pipette											
1	4	14	32	44	50	53	55·5	56	57	57	57·5	58
2	3	7	12	20	29	40	46	50	52	53	54	55
3	3	10	17	25	32	38	44	48	50	51	52	53
4	2	5	9	14	21	29	35	41	43	44	45	46
5	4	10	21	33	41	45	47	48	49	50	50·5	50·5
6	3	6	10	14	19	25	31	36	40	43	45	47
Average	3	8·5	17	25	32	38	43	46·5	48·5	49·5	50·5	51·5

TABLE VII
(*Amœbic Dysentery Cases*).

Case No.	TIME IN MINUTES											
	10	20	30	40	50	60	70	80	90	100	110	120
	Divisions of the Pipette											
1	3	9	16	25	35	43	49	53	56	58	60	61
2	2	5	9	13	18	24	28	32	35	38	40	42
Average	2·5	7	12·5	19	26·5	33·5	38·5	42·5	45·5	48	50	51·5

TABLE VIII
(*Malaria Cases*).

Case No.	TIME IN MINUTES											
	10	20	30	40	50	60	70	80	90	100	110	120
	Divisions of the Pipette											
1	5	20	40	55	60	61·5	62	62·5	63	63·5	64	64
2	2	4	6	9	13	19	24	28	32	36	39	42
3	3	7	13	20	25	30	34	37	40	42	44	46
4	4	10	17	24	32	40	45	50	53	56	58	60
5	2	5	8	11	15	20	25	27	29	30	31	32
6	2	4	6	10	14	19	23	27	30	33	36	38
Average	3	8	15	21·5	26·5	31·5	35·5	38·5	41	43	45	47

TABLE IX
(*Osteomyelitis Cases*).

Case No.	TIME IN MINUTES											
	10	20	30	40	50	60	70	80	90	100	110	120
	Divisions of the Pipette											
1	17	35	60	70	74	75	76	76·5	76·8	77	77	77
2	4	10	21	34	47	52	56	59	60	61	62	62·5
Average	10·5	22·5	40·5	52	60·5	63·5	66	68	68·5	69	69·5	70

The test was then repeated after varying intervals in the case of ten patients with Pulmonary Tuberculosis five of whom showed an improvement in their general condition and the other five an aggravation of the process at the end of that interval. These latter ultimately succumbed to the disease after a few days. The curves obtained in each case are given in figs. 8 to 17.

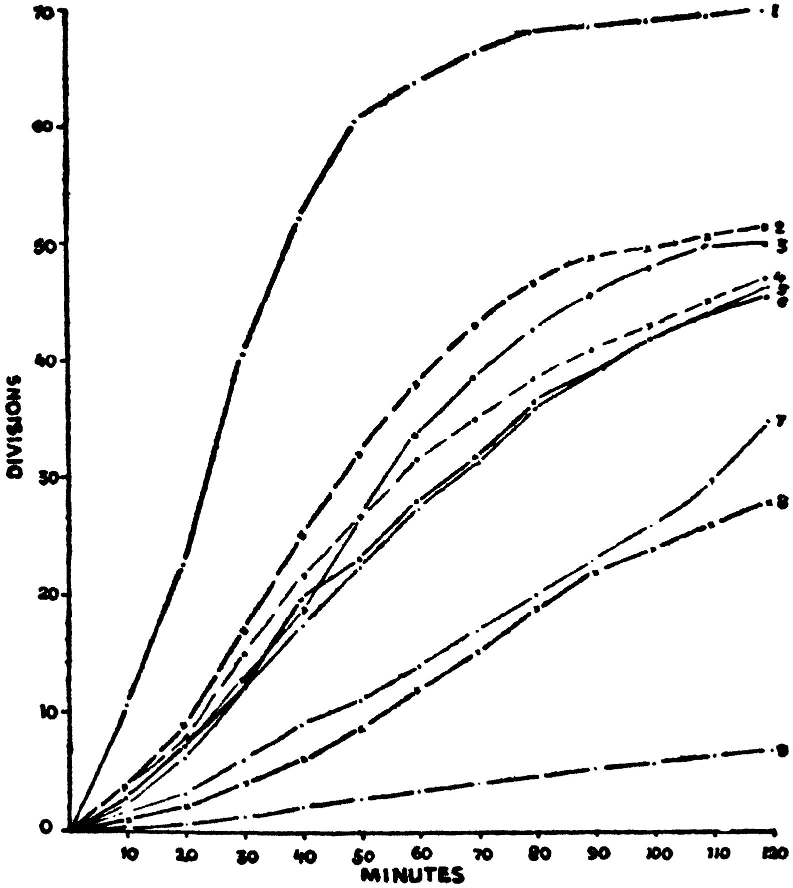

FIG. 7.—Compares the curves of various diseases studied with the average normal. 1. Osteomyelitis (2 cases); 2. Pneumonia (6 cases); 3. Amoebic Dysentery (2 cases); 4. Malaria (6 cases); 5. Bone Tuberculosis (4 cases); 6. Pulmonary Tuberculosis (50 cases); 7. Intestinal Tuberculosis (1 case); 8. Gland Tuberculosis (3 cases). 9. Average normal.

All these observations show that—

(a) The sedimentation of R. B. C. in all the tubercular conditions is definitely faster than in normal health. (Fig. 4).

(b) Even the lowest tubercular curve is much higher than the average or the highest normal curve. (Figs. 5 and 6).

(c) The sedimentation is faster in Pulmonary and Bone Tuberculosis than in the Gland and the Intestinal types. (Figs. 3 and 4).

(d) The average rate in the Pulmonary and the Bone types and that in the Gland and the Intestinal types are almost equal. (Fig. 3)

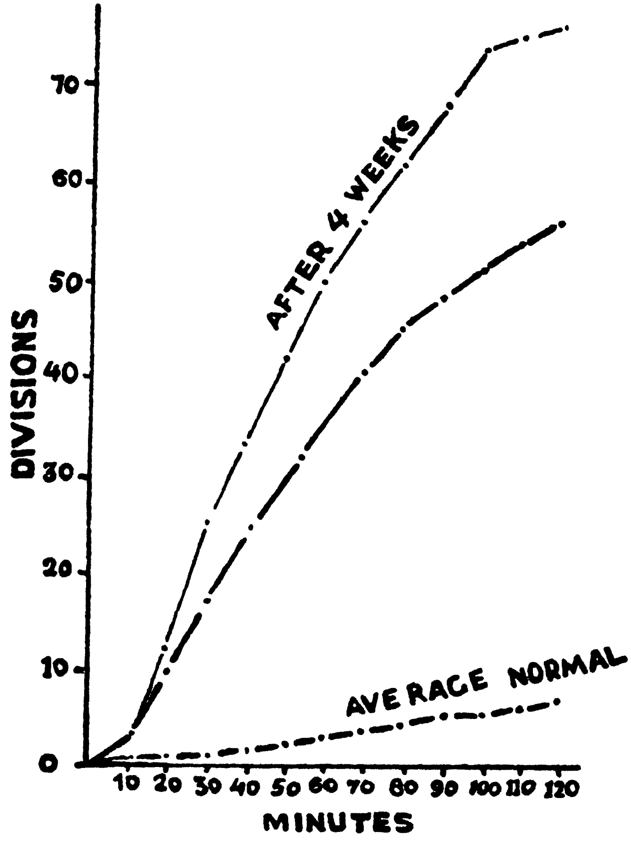

FIG. 8.—Curves of patient in whom the test was repeated after 4 weeks. Patient died.

(e) The rate is also faster in Osteomyelitis, Pneumonia, Amoebic dysentery, and Malaria in their acute stages than in both normal and tuberculous conditions. (Fig. 7).

(f) In Pulmonary Tuberculosis the rate either remains the same or goes higher than before in cases where the disease progresses (Figs. 8 to 12); while with the decline of the tubercular process shown by an improvement in the general condition the rate shows a diminution. (Figs. 13 to 17).

From all this therefore one may infer that—

(i) The sedimentation test is not necessarily specific in the diagnosis of Tuberculosis, but

(ii) Since the rate of sedimentation is definitely faster in that condition than normally it may serve as a good negative test; for instance in a particular case if the rate is normal while the clinical signs are suspicious the odds are in favour of absence of an active tuberculous condition.

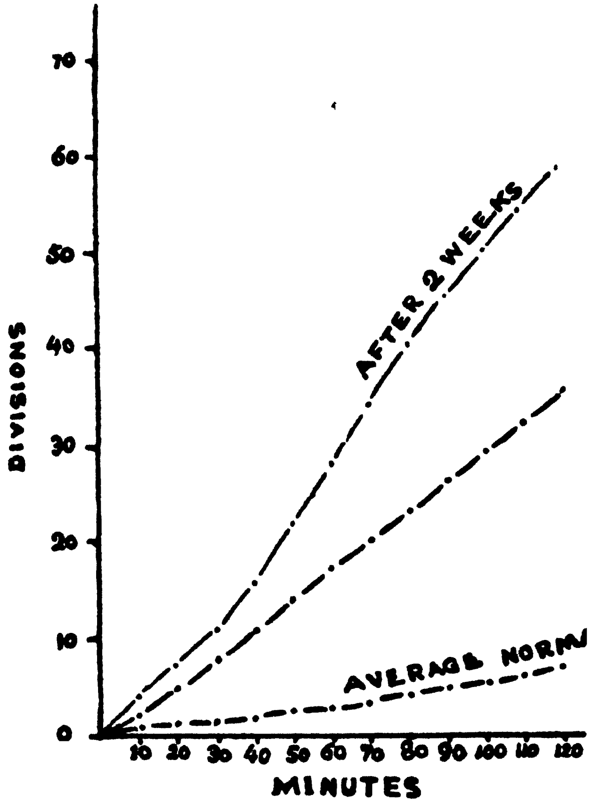

FIG. 9.—Curves of patient in whom the test was repeated after 2 weeks. Patient died.

(iii) The rate of sedimentation may be an index of the septic absorption in the blood of inflammatory products. That is why probably in Osteomyelitis the rate is higher than in Pneumonia or Amoebic dysentery. In Malaria it may be due to destruction of the blood cells by the malarial parasite leading to the absorption of their disintegrated protein products. In the Pulmonary and the Bone type of Tuberculosis also the curves are higher than those of Gland and Intestinal types probably because in the former two there is more possibility of secondary infection owing to direct communication with the exterior followed by increased inflammatory absorption (the lungs are of course always open to the exterior while it must be remembered that all the cases of the bone type studied presented sinuses open to the exterior) than in the latter two.

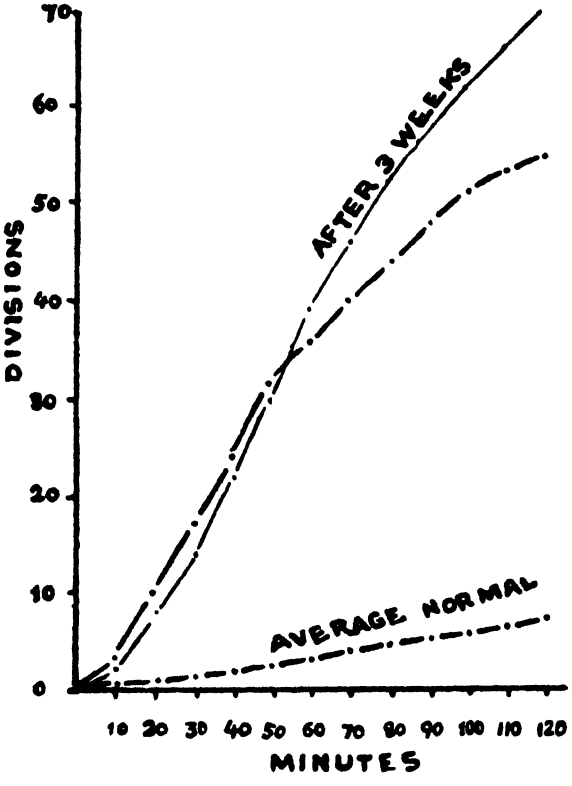

FIG. 10.—Curves of patient in whom the test was repeated after 3 weeks. Patient died.

(iv) The test may prove useful in the prognosis of a given case or in following up its progress in response to a prescribed course of treatment.

II

BLOOD PRESSURE IN TUBERCULOSIS.

The Blood Pressure, systolic and diastolic, in both the brachial arteries in each case, was observed in the following cases:

(*a*) 30 apparently normal individuals, and

(*b*) 54 patients suffering from Chronic Pulmonary Phthisis in various stages.

The instrument used was the Tycos sphygmomanometer, checked with a mercury manometer. All the subjects under observation were males and were placed in the recumbent position. Their ages varied between 20 and 40. The pressure was taken in every case an hour or so before the midday meal after allowing sufficient time for the initial temporary reflex spasm in the arterial walls to subside. The auscultatory method was used with an added check by palpation of the radial artery. The diastolic figure was taken at the beginning of the last phase when the loud sharp sound just begins to get muffled and not when the sound entirely disappears.

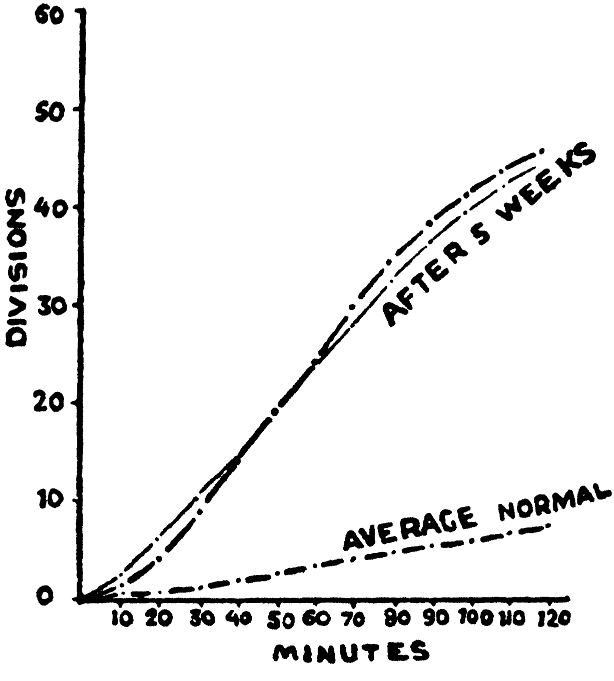

Fig. 11.—Curves of patient in whom the test was repeated after 5 weeks. Patient died.

The maximum, minimum and average figures observed are given below :—

Subject	Systolic Pressure (in mm. Hg.)						Diastolic Pressure (in mm. Hg.)						Pulse Pressure (in mm. Hg.)		
	Rt. Arm			Lt. Arm.			Rt. Arm			Lt. Arm					
	Max	Min	Average	Max	Min	Average	Max	Min	Average	Max	Min	Average	Max	Min	Average
Normal	130	108	119	128	110	119	100	74	87	98	74	87	37	24	32
Tubercular	124	90	103	122	88	103	86	60	74	86	62	74	44	21	29

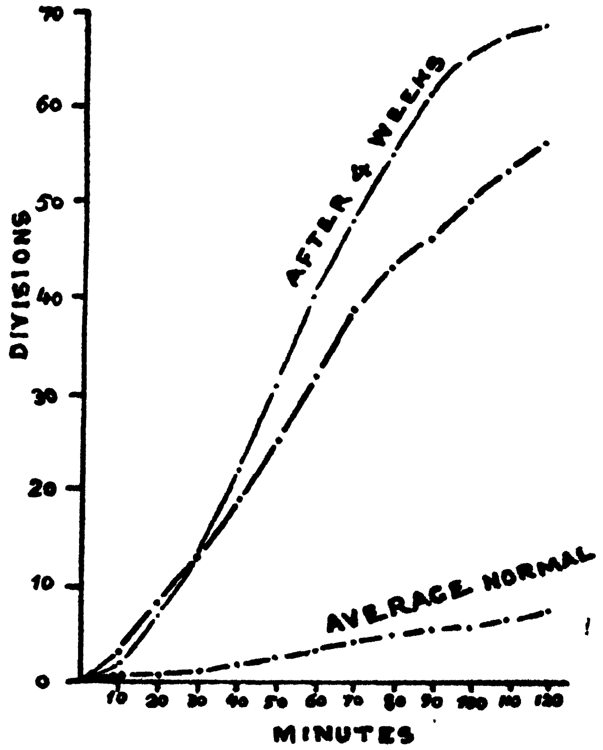

FIG. 12.—Curves of patient in whom the test was repeated after 4 weeks. Patient died.

Conclusion : Blood Pressure both systolic and diastolic is low in Pulmonary Tuberculosis as compared with the normal figures.

The pulse pressure, however, does not show a great fall and if it be taken as a measure of the ventricular force then one may say that the heart muscle in tubercular subjects does not suffer to the same extent as the other factors influencing the blood pressure in the body.

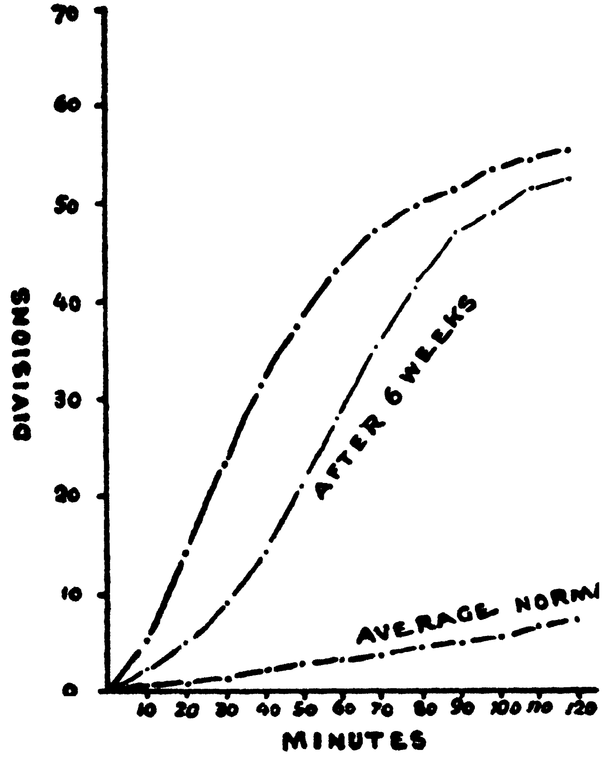

FIG. 13.—Curves of patient in whom the test was repeated after 6 weeks. Patient improved.

III

BLOOD CALCIUM IN TUBERCULOSIS

Calcium in blood serum of 52 patients suffering from Pulmonary Tuberculosis in various stages was quantitatively determined by the Clark and Collip's method (J. of Biol. Chem. 1925 LXIII. 461).

The figures obtained were :—

	mgm. per 100 cc. blood
Maximum	10·2
Minimum	6·9
Average	8·1

Conclusion: Compared with the normal figures given by Mukherjee for the Bengalees (Biol. Abst. No. 11180–June 1930) *viz.*, 9·6 mgm., these figures show a marked reduction of calcium in the blood of phthisical subjects.

IV

BLOOD SUGAR, BLOOD UREA, AND BLOOD CHLORIDES IN TUBERCULOSIS.

These were determined in 10 subjects of the same disease. The fasting blood sugar was estimated by Maclean's ("Modern methods in the diagnosis and treatment of Glycosuria and Diabetes"—1924) the urea content by Van Slyke's ("Recent advances in Medicine"-Beaumont and Dodds—1928), and the chloride content of whole blood by Whitehorn's (Cole's Physiological Chemistry—1926) methods respectively.

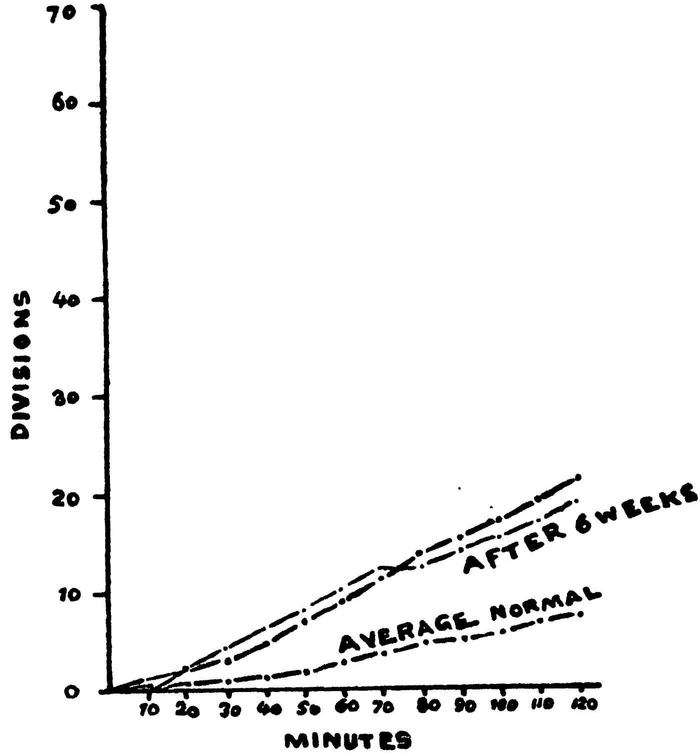

FIG. 14.—Curves of patient in whom the test was repeated after 6 weeks. Patient improved.

The figures obtained were :—

Blood Sugar :

	mgm. per 100 cc. blood
Maximum	118
Minimum	93
Average	104

Blood Urea :

	mgm. per 100 cc. blood
Maximum	29
Minimum	23
Average	25·5

Blood Chlorides :
(whole blood)

	mgm. NaCl per 100 cc. blood
Maximum	520
Minimum	475
Average	498

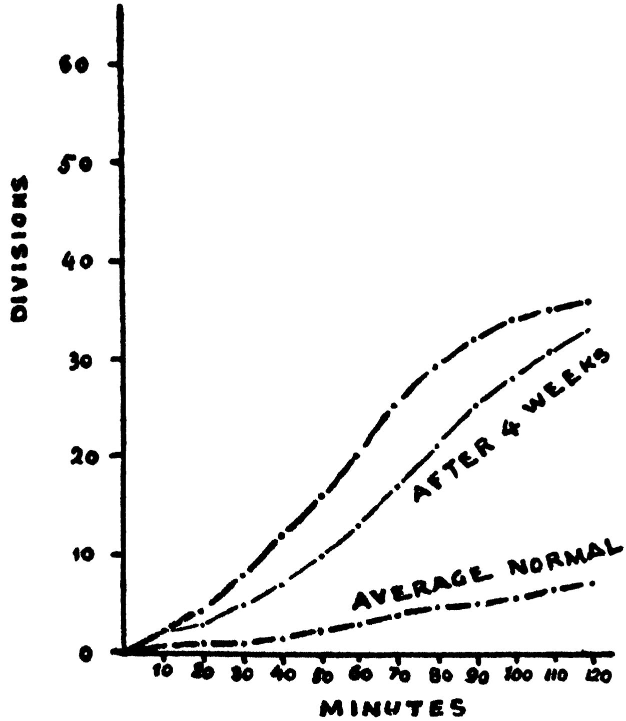

FIG. 15.—Curves of Patient in whom the test was repeated after 4 weeks. Patient improved.

Conclusion : The above data show that there is no marked deviation from the normal.

In concluding this résumé I must thank Major S. L. Bhatia, I. M. S., Professor of Physiology and Dean, Grant Medical College, Bombay, for his kind suggestions from time to time; thanks are also due to all those patients and normal subjects who were kind enough to spare their specimens of blood for the work.

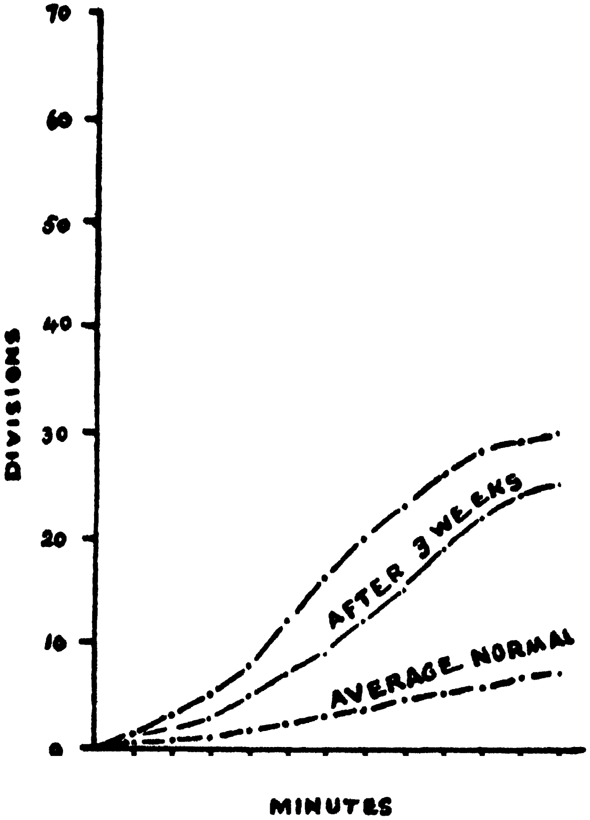

FIG. 16.—Curves of patient in whom the test was repeated after 3 weeks. Patient improved.

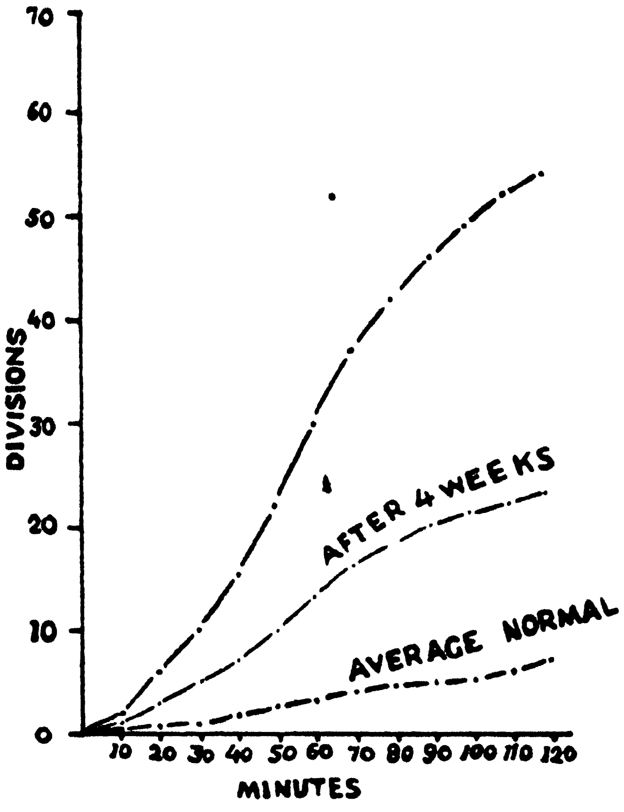

FIG. 17.—Curves of patient in whom the test was repeated after 4 weeks. Patient improved.

Abstracts of the M. Sc. Theses in Botany for 1931-1932

I.—"*Carbon dioxide assimilation of the leaves of the rice plant*" *Oryza Sativa, L.* By J. J. CHINOY, M. Sc. (Dept. of Botany, Royal Institute of Science, Bombay.) Guide :— PROF. R. H. DASTUR.

" As no data is collected about the photosynthetic activity of the leaves of the Rice plant by direct measurements, it is undertaken to measure the rate of photosynthesis of the leaves of the Rice plant at different stages of growth.

The photosynthetic activity of the leaves in this investigation is measured in two ways : (1) by determining the carbohydrate contents of the leaves in the morning and in the evening: and (2) by measuring the absorption of carbon-dioxide from the air under controlled and uniform conditions of experiments.

In the first method the leaves are killed and extracted with alcohol taking necessary precautions. The sugars are then separated from other substances. The starch is hydrolysed by takadiastase and is converted into dextrose and maltose.

All sugars are estimated as hexoses. Cane-sugar and maltose are hydrolysed to hexoses before estimations. A colorimetric method of estimating sugars first used by Follin and Wu (1918) and subsequently modified by other workers is used in this investigation with further modifications.

A sample of leaves is taken in the morning and analysed for carbohydrates. Another sample is taken the same evening and is similarly analysed. 20 such double carbohydrate analysis of the leaves are made on different days from July to October. On two occasions the leaves are analysed for carbohydrates every six hours during 24 hours.

In the second method carbon-dioxide absorption of the leaves of the Rice plant is measured by the continuous gas current method. A special leaf chamber to hold four leaves of the Rice plant is devised. Ordinary air is used and is circulated through the leaf-chamber at the rate of about 100 litres per hour. The carbon-dioxide of the air before and after it passed through the leaf-chamber is estimated in two sets of absorption apparatus consisting of Reiset towers containing NaOH solution of known strength.

From the results obtained by the two methods the following periodicity in the photosynthetic activity of the leaves of the Rice plant is noticed. The photosynthetic activity rises rapidly soon after transplantation. It remains fairly uniform in August after which there is a depression in September. There is a sudden rise in the photosynthetic activity in October and it reaches its second maximum during that period. There is a big fall in the rate of photosynthesis soon after.

The same features of the photosynthetic activity are noticed in the results obtained by the two methods."

(Published in the Indian Journal of Agricultural science.)

II.—" *Effect of plane-polarised light on the formation of carbohydrates in leaves.*" By R. D. ASANA, (Dept. of Botany, Royal Institute of Science, Bombay.) Guide :— Prof. R. H. DASTUR.

" In recent years the study of the effect of polarised light on chemical reactions and biological processes has engaged considerable attention of scientific investigators. It has been suggested that the polarised light may be one of the asymetric forces outside the plant responsible for the formation of optically active substances in the photosynthetic process. It was, therefore, undertaken to study the effect of polarised light on the formation of carbohydrates in living leaves.

Various unsuccessful attempts to tackle the problem in a satisfactory manner have been described. The arrangement of the apparatus and the attainments of a sufficiently large and intense beam of strongly polarised light presented chief difficulty. Ultimately a floodlight lamp was used to obtain a large and intense beam of reflected polarised light.

A series of experiments was performed with the leaves of Allium cepa, L. and Helianthus annus, L. The amount of total carbohydrates formed in leaves in polarised light was equal to, greater or less, than that formed in the non-polarised light. On examining the results statistically the differences found are insignificant.

Similar experiments were performed in sunlight. The arrangement of the apparatus is described. The results obtained with Helianthus annus, L. and Raphanus sativus were similar to those obtained in artificial light. The results show that in polarised light photosynthesis goes on as well as in ordinary light. The formation of starch occurs in the polarised light which contradicts the conclusions drawn by Semmens."

(Published in full in the *Annals of Botany*, October 1932.)

III.—" *Study of some Aspect of the Physiology of the Tendrils of Cucurbitaceae.*" By M. C. BILLIMORIA, M. Sc. (Botany Dept., Royal Institute

of Science, Bombay). Guide:—
PROF. R. H. DASTUR.

"The following aspects of the Physiology of the tendrils of Cucurbitaceae were studied with a view to understand the mechanism of curvature of tendrils when stimulated by contact.

(1) The respiration of tendrils at different stages.

(2) The internal temperature of tendrils at different stages.

(3) The degree of turgidity of tendrils at different stages.

(4) The suction pressure of tendrils at different stages.

Measurements of respiration show that the curled tendrils have very little respiratory activity in comparison to straight tendrils. There is no increased output of CO_2 when the tendrils curl. As the age advances the respiration decreases.

The internal temperature of the tendrils also support the view that very little energy is given out when the tendril is stimulated to curl *i. e.* there is no rise of temperature on stimulation. The results show that the temperature in the plant organs is lower than that of the atmosphere. The temperature at the base is lower than at the apex. In a curled tendril it is lower than that in the straight tendril of corresponding length. Internal temperature of the straight tendrils of the same lengths are different. Two curled tendrils of the same lengths can have different temperatures owing to the difference in the age of curling. The temperatures of the stimulated tendrils fluctuate, but the fluctuations are of the same degree before and after stimulation.

The degree of turgidity of tendrils is determined by determining the water contents of the tendrils per unit and length per unit dry weight. The results show that as the age of the tendril advances the water content increases both per unit length and per unit dry weight in all the species of Cucurbitaceae examined, and that in the fully grown tendril the water content reaches the highest value.

The suction pressure of the tendrils of Cucurbitaceae increases with length in case of straight tendrils. The suction pressure at the apex is higher than at the base in all the species examined. The suction pressure in the straight tendrils is higher than that in the curled tendrils of corresponding lengths.

The results obtained from the study of the above-mentioned aspects of the physiology of tendrils do not support the physiological view of the mechanism of curvature of tendrils.

The discovery of small pits in the cells which according to Dastur and Kapadia undergo physical elongation when curve takes place, supports the physical view expressed by them for the mechanism of curvature of tendrils in Cucurbitaceae."

(Published in full in the *Journal of Indian Botanical Society*, Vol. XI, No. 2, 1932.)

IV.—"*The osmotic and suction pressures of the Rice plant Oriza Sativa, L. when treated with different Salts: A method of determining the salt requirements of plants.* By R. E. COOPER, M. Sc. (Dept. of Botany, Royal Institute of Science, Bombay.) Guide:—PROF. R. H. DASTUR.

"In all the previous investigations dealing with the salt requirements of the rice plant, no attempt is made to determine the changes produced in the osmotic and suction pressures of the plants kept either in culture solutions of different compositions or when treated with certain fertilizers in the soil. It was therefore considered necessary to investigate the changes produced in the osmotic and suction pressures of the rice plant under different treatments. It would also be of interest to study the changes in the two pressures of the plant when treated with salts which are not absorbed in appreciable quantities either during the life cycle or at certain stages of growth of the plant.

If the results of the investigation would show that there is a rise in the osmotic and suction pressures of the rice plant when treated with salts which are absorbed and if no such rise is noticed when the rice plant is treated with salts which are not absorbed, it would be worth while to investigate if this method can be developed to determine the salt requirements of plants.

The effect on the osmotic and suction pressures of roots and leaves of the rice seedlings (Kolamba variety No. 42) of different stages of growth when treated with solutions of ammonium sulphate of concentrations varying from N/100 to N/900 is studied. Similarly the effect on the osmotic and suction pressures of the roots and leaves of the rice seedlings when kept in solutions of KNO_3 of concentrations varying from N/100 to N/1500 is studied. The results of these experiments show that the osmotic and suction pressures of the roots and leaves of the rice seedlings in ammonium sulphate solutions are generally higher than those of the same organs of the rice seedlings in KNO_3 solutions except in solutions of $(NN_4)_2$ SO_4 of lowest strengths. There is also a big rise in the two pressures after the seedlings are transferred to $(NH_4)_2$ SO_4 of concentrations varying from N/100 to N/500, while no such rise is noticed in the corresponding solutions of KNO_3.

The chemical analysis of the solutions, after the seedlings had remained in them for eight days, shows that NH_4 and SO_4'' ions are considerably absorbed, varying according to the concentrations of $(NH_4)_2SO_4$ solutions, while NO_3' ions are absorbed in minute quantities from different solutions of KNO_3.

Similar pot culture experiments both in garden soil and in pure sand show that there is a rise in the osmotic and suction pressures of the rice seedlings manured with $(NH_4)_2$ SO_4 solutions as compared with the unmanured seedlings, while very little rise is observed in the two pressures of the seedlings when manured with KNO_3.

The changes in the osmotic and suction pressures of the roots and leaves of the rice plant in single salt solutions of calcium sulphate and potassium sulphate are studied. The results show that the pressures are higher in calcium sulphate solutions than in potassium sulphate solutions.

The effect on the osmotic and suction pressures of the roots and leaves of the rice plants when treated with ammonium sulphate and potassium nitrate solutions in later stages of growth is studied with similar results as mentioned above.

The osmotic and suction pressures of the roots and leaves of the rice seedlings in normal culture solutions are first recorded. The changes in the two pressures are then studied in culture solutions from which potassium or potassium and nitrogen, or ammonium, or calcium is omitted. Distinct differences in the two pressures are observed.

Similar experiments with the roots and leaves of Tradescantia zebrina, Hort. and Zea Mays, L. are performed to see if any rise or fall in the osmotic and suction pressures is observed when a salt that is required by the plants is supplied or omitted. The results show a rise when the salt is added and a depression when it is omitted.

The suggestion is put forward as a result of seven hundred and fifty determinations of the osmotic and suction pressures that the most essential of the salts required by plants can be determined by changes in the osmotic and suction pressures of their roots and leaves."

(Published in full in the *Indian Journal of Agricultural Science*, Vol. II, Part II, April 1932.)

The Late Dr ACCACIO GABRIEL VIEGAS, L. M. & S., F. C P. S.

Obituary

Dr. Accacio Gabriel Viegas.

It is with deep regret that we record the death of Dr. Accacio Gabriel Viegas, which took place at Bombay on the 22nd February, 1933. He was then in his 77th year. A man of outstanding character, and marked ability, and one who had rendered valuable service to his fellow-men, Dr. Viegas will be widely missed by the citizens of Bombay and especially by the Bombay University.

He was born at Goa on 1st of April, 1856, and came of an ancient and highly respectable family. After studying Portuguese and Latin, he came to Bombay in 1872 and joined the Preparatory Class in St. Xavier's School. In 1875, he took up the study of Medicine in Grant Medical College. After a distinguished college career, he passed the final Examination for the degree of L.M. & S., being placed in the First Class, in 1880.

After qualifying he began his medical practice, and soon established his reputation among the merchants of Mandvi. It was with their support that he entered the Bombay Municipal Corporation in 1888 as an elected member. His perseverance, industry and thorough grasp of Municipal problems, his resourcefulness in debate, and profound knowledge of Municipal procedure brought him to the front rank of Municipal Corporators. It was no surprise therefore, when at the triennial Municipal elections he was returned to the Corporation from the Mandvi Ward each time at the head of the poll. He continued to represent the Mandvi Ward till 1903, when he secured election through the Justices of the Peace. In 1903-1904, he was elected Chairman of the Standing Committee, of which he had been a member for fourteen years. In 1906, he was unanimously elected President of the Corporation for that year, being the first Indian Christian to hold that post. From 1907-1919, there was a break in his connection with the Municipal Corporation; but from the year 1919 till the time of his death he was again an elected member of that body. During his long career as an elected City Father, he took a very keen interest in, and kept an ever vigilant watch over, the sanitation and Public Health of this city and its finances. He ever championed the cause of the poor, the employees in the humbler ranks and secured for them better prospects. He also helped to re-organize the Health Department specially with a view to stamp out Malaria. His work in connection with the drainage of the North of the Island will always be remembered. He advocated an extension of free compulsory Primary Education. He was always a bold and vigorous fighter and was an admirer and staunch supporter of independent men like Sir Pherozeshah Mehta.

He was one of the oldest Trustees of the old Board of the Improvement Trust from its inception in 1898 to 1907 and a member of the Improvements Committee and its various Sub-Committees from 1926-1930. He fought hard in regard to the question of amalgamation of the Improvement Trust with the Municipality. His chief watch-words were retrenchment of expenditure with due regard to efficiency.

The greatest and most valuable service rendered by Dr. Viegas to the city of Bombay was his discovery of the outbreak of plague in the city in 1896, when he urged upon the authorities the necessity of taking effective measures to combat this dire disease which exacted a heavy toll of life. In recognition of this, Government appointed him a member of the First Plague Committee. He was also a Plague Volunteer and Chairman of the Plague Volunteer Committee for some years.

Dr. Viegas had an equally useful career in the University of Bombay of which he was a Fellow for a period extending over 43 years. He rendered distinguished services to the University in various capacities such as Dean of the Faculty of Medicine in 1906 and as Syndic, etc. His connection with the University remained unbroken until the time of his death. As a Fellow of the University he took special interest in the institution of the Department of Chemical Technology. His efforts to economise expenditure in all directions were untiring.

The members of the Senate will ever miss his vigorous personality, his charm of manner, his sincerity of purpose and his courage. His death will be felt as a personal loss by one and all in the University.

He was a foundation Fellow and member of the Council of the College of Physicians and Surgeons of Bombay till the time of his death. In 1912, he was a nominated member of the Bombay Medical Council. He held this appointment for 10 years. For some years, he was Chairman of the Advisory Board of the Cama and Albless Hospitals.

In spite of his large medical practice and multifarious civic activities he found time to devote to the affairs of his own community.

Dr. Viegas was an orator of a high order and possessed great literary skill and command of the English Language, but his one chief characteristic was his simplicity of manner and warmheartedness. He was loved by all who came in contact with him. By his death the Medical Profession has suffered a great loss and the city of Bombay has lost one of her most devoted sons. His life, dedicated as it was to the good of the public, will be a source of inspiration to all.

S. L. BHATIA

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